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URBANA

REPORT OF INVESTIGATIONS — NO. 79

FELDSPAR IN ILLINOIS SANDS

A Study of Resources

BY

H. B. WILLMAN

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Topographic Mapping in Cooperation with the United States Geological Survey.

This Report is a Contribution of the Industrial Minerals Division.

April 15, 1942

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FELDSPAR IN ILLINOIS SANDS

BY

H. B. WILLMAN

ABSTRACT

Extensive deposits of sand in Illinois contain 20 per cent feldspar, and some deposits contain more than 30 per cent. As no feldspar is mined in the State or in the Middle West, but considerable tonnages are shipped in from such distant states as Colorado, North Dakota, and North Carolina, it appears that feldspar might be produced profitably from Illinois sands if an economical process for separating feldspar of commercial grade from the sand can be developed. The fact that feldspar can be separated from crushed granite by flotation suggests that feldspar possibly can be separated from the Illinois sands.

In view of the foregoing, a two-fold investigation was undertaken by the Illinois Geological Survey to determine: (1) the extent and nature of the Illinois feldspar-bearing sands, and (2) the most economical methods of separating and preparing commercial grades of feldspar from the sands.

This report covers the first portion of the investigation, describes the distribution and size of Illinois sand deposits, and gives the results of sieve and mineral analyses of more than a hundred samples representing typical deposits throughout the State. It shows that enormous deposits of feldspar-bearing sands occur in many parts of the State, especially the northern and western parts. Much of the feldspar-bearing sand has little or no present commercial use.

The types of materials investigated were dune sands, glacial outwash sand and gravel, river sand, lake and beach sand, preglacial sand, and sands produced by crushing sandstones. The sandstones and preglacial sands were found to contain comparatively little feldspar, but the other types commonly contain 15 to 25 per cent feldspar with a few sands containing more than 30 per cent.

Data regarding the percentage of feldspar in the different types of sand are summarized on page 13, a classification of Illinois sand deposits on the basis of grain size and carbonate content is given on page 14, and a summary of the possible advantages and disadvantages of the various types of sands as sources of feldspar is presented on page 25.

INTRODUCTION

The state of Illinois has enormous deposits of dune, river, and glacial sands which at present have little commercial use. During the course of studies to find additional uses for these sands it was discovered that many of them contain as much as 20 per cent and some more than 30 per cent feldspar. The possibility that these sands might provide a new commercial source of feldspar offered a promising field for investigation, especially as large quantities of feldspar produced from pegmatite deposits in Colorado, South Dakota, and North Carolina and other Eastern States are used in Illinois and the Middle West in the manufacture of glass, pottery and enamels.

Certain features of the sand deposits and the present feldspar industry favor the use of the sand as a source of feldspar, namely:

(1) The cost of mining sand is low as compared with that of pegmatite deposits which require drilling, blasting, crushing, and in many cases hand-sorting.

(2) The feldspar in the sand is of such grain size that for some uses it would require no grinding. The 200-

mesh commercial grades could be produced from sand with less grinding than from pegmatite feldspar.

(3) The cost of the sand should be low because large areas of sand in Illinois are of relatively low value for agriculture.

(4) It is possible that the sand from which the feldspar has been removed may find some use, and that the magnetite, ilmenite, and other minerals occurring in small amounts in the sands may have value as by-products.

(5) Production of feldspar near the consuming centers of the Middle West would save freight charges. The current freight charge from western shipping points to Chicago is reported to be $7.37 a ton.

(6) Because of the low cost of mining the sand and the comparatively low freight charges probable on feldspar to Middle West consumers, a considerable margin is available for separating the feldspar from the sand.

(7) It has recently been demonstrated that feldspar can be separated from quartz by froth flotation and agglomerate tabling.[1]

(8) Recent technical advances in the methods of identifying feldspar make it possible to determine rapidly the approximate quantity of feldspar in numerous deposits.

The quality of the feldspar which can be produced commercially from the Illinois sands is, of course, a primary consideration. Although the final answer to this question cannot be given at present, preliminary experiments by the Geochemical Section of the Survey indicate that it is possible to produce by laboratory methods a feldspar concentrate which is as low in iron oxide and as high in alumina as most commercial feldspars. The feldspar so separated made a crystal glass.

For these reasons an investigation was undertaken by the Illinois Geological Survey to determine, (1) the amount of feldspar and other minerals in the sands and the general distribution and size of the deposits, and (2) the quality of the feldspar and the best commercial methods of separating it from the other constituents of the sands. The first phase of the study has been conducted by the Industrial Minerals Division of the Geological Resources Section of the Survey and the second is being carried out by the Industrial Minerals Division of the Geochemical Section.

This report gives the results of the first phase of this investigation and relates to resources.

Acknowledgments

This investigation was made under the supervision of J. E. Lamar, geologist and head of the Industrial Minerals Division. Robert R. Reynolds assited in the field and laboratory studies. Other members of the Survey staff were consulted on various phases of the investigation, especially J. S. Machin on the separation and quality of the feldspar, R. E. Grim on the problems in mineralogy, and George E. Ekblaw on the distribution of sand and gravel deposits.

The maps of the sand and gravel deposits are compiled from published reports and unpublished maps in the files of the Illinois Geological Survey. The county soil maps of the University of Illinois Agricultural Experiment Station were used in some areas.

PROCEDURE

Samples

Because of the large number of extensive sand deposits in Illinois, samples were collected from the various types of deposits in different parts of the State. After these samples had been studied additional samples were taken to supply further data about the most promising deposits. Samples of about 5 pounds each were collected from roadcuts, outcrops, pits, and auger borings. Because of inadequate exposures, it was usually not possible to secure samples from the entire thickness of the sand in any deposit.

The samples of river sand were mostly obtained by combining small samples collected at many places on the surface

[1] O'Meara, R. G., Norman, J. E., and Hammond, W. E., Froth flotation and agglomerate tabling of feldspars: Am. Ceramic Soc. Bull., vol. 18, pp. 286-292, 1939.

of a bar or beach exposed at low water. Therefore they do not represent any great thickness of sand, but they indicate the nature of the sands currently handled by the rivers.

The location, character, thickness sampled, and thickness of the overburden of the samples are given in table 1, (p. 53).

Sieve Analyses

In the laboratory the grain size and mineral composition of the samples were determined and the results are given in table 2, pages 57-87. A preliminary examination of the pebbly sands and the gravels showed that the material coarser than 8-mesh contained comparatively little feldspar, and the feldspar present in material coarser than 8-mesh occurred mostly in mineral aggregates which are largely fragments of igneous and metamorphic rocks. In a commercial process any material coarser than 8-mesh, and perhaps even somewhat finer-grained material, would probably be screened out and discarded, or finer-grained sands would be used. Consequently material coarser than 8-mesh was sieved from the samples, its percentage was determined, and the sieve analyses were made on the material finer than 8-mesh by the following procedure.

The entire sample was quartered to a 50- or 100-gram sample depending on the character of the material. If the sample was noncalcareous and originally contained no material coarser than 8-mesh, a 50-gram sample was used. If it was calcareous, or if it originally contained some material coarser than 8-mesh, and was therefore relatively coarse, a 100-gram sample was used. The accurately weighed samples were agitated in water with a motor-driven malted-milk stirrer for about five minutes. They were then wet-sieved on a 270-mesh sieve, dried, and weighed. From the loss in weight the percentage of material finer than 270-mesh was calculated. The material which was retained on the 270-mesh sieve was then sieved on Tyler standard sieves, ranging from 10- to 270-mesh (listed in table 2), using a rotap shaker for 15 minutes. Usually a little material passed the 270-mesh sieve and its amount was added to the amount of material finer than 270-mesh previously determined by washing. The results of these sieve analyses are recorded under *Condition A* in table 2.

Determination of Acid-soluble Material

To determine the percentage of carbonates and iron oxides in the calcareous samples and to prepare the samples for later mineral determinations, the sieve fractions of the calcareous samples were recombined (omitting the material finer than 270-mesh) and the sample was digested in hydrochloric acid (1 part concentrated acid and 2 parts water) until effervescence ceased. The residue was then filtered, washed, dried, and weighed, and the total per cent soluble was calculated. It is given as the total under *Condition C* in table 2. The sample was then sieved again, using the same sieves as before, and the fractions were weighed. This sieve analysis is given under *Condition B* in table 2. From the loss of weight of each fraction the per cent of that fraction soluble in acid was calculated, as given under *Condition C* in table 2. The change in weight of fractions weighing less than 0.5 gram was not considered significant, and their percentage soluble is not recorded.

This method gives a fairly accurate result for the total amount of acid-soluble material in the sample, but the solubility data for the individual sieve sizes are less accurate. In the latter a variable error arises from resieving, from the breakdown of aggregates when acid-treated, and from the insoluble residues in the calcareous grains. The last two errors cause the finer sieve sizes to show a lower solubility than actually occurs; rarely they cause the finer sieve sizes to gain in weight after the acid treatment and resieving.

The acid-soluble material consists largely of carbonates, mostly grains of limestone and dolomite, and of acid-soluble iron oxide, mostly stain of limonite on the grains. A small percentage of other acid-soluble minerals is also present. As the amount of acid-soluble iron oxide is commonly between 0.5 and 1.0 per cent, the acid-soluble material over that amount is predominately carbonates.

Mineral Analyses

The mineral composition of the samples was determined by mounting sand of selected sieve sizes on glass slides, etching and staining certain minerals to permit ready identification, and determining the percentage of the minerals by counting the grains of each, using a binocular microscope. The procedure was as follows:

Two to four sieve fractions of most samples, more of a few samples, were selected for study. The fractions of the calcareous samples were ready for mounting after the sieve analysis, because the iron oxide films on the grains had been removed in the acid treatment. The fractions of the noncalcareous samples, however, required digestion in hydrochloric acid to remove the iron oxide films. Each fraction was quartered, using a miniature Jones-type splitter, to a sample small enough to be mounted on a glass microscope slide. The slides were prepared by painting one surface with a thin solution of Canada balsam in acetone and heating on a hot plate until the balsam when cool was hard but not brittle. The sand grains were spread thinly and evenly over the surface of the solid balsam. Then a very low bunsen-burner flame was passed directly but rapidly over the grains. This was repeated until the balsam melted and adhered to the grains, as shown by slightly jarring the slide. Too much heating will cause the balsam to cover the grains and interfere with later tests.

The staining procedure[2] consisted of covering the grains with a few drops of hydrofluoric acid (48 per cent) for one minute, gently washing off the acid by dipping the slide in water, then immediately covering the grains with a 10 per cent solution of freshly made sodium cobaltinitrite, and after a minute again washing the slide and permitting it to dry. It was then ready for study with a binocular microscope. Using a magnification that covered a field containing 25 to 50 grains, all the grains of each mineral in the field were counted. Usually a row of adjacent fields completely across the slide, sometimes several rows, was counted, or until 500 to 1,000 grains were counted. Slides of grains coarser than 28-mesh usually did not contain 500 grains but on these slides more than 200 grains were counted.

The percentages of the various minerals, given in table 2, are all by number of grains rather than by weight. Although the feldspars range in specific gravity from a little higher to a little lower than quartz, they are mostly near enough to quartz that the percentage by number of grains is roughly equivalent to the percentage by weight. Chert and shale also have about the same percentage by weight as by number, but the "heavy minerals" have specific gravities ranging from about 3 to 5 and the percentage by weight is approximately 1.5 times the percentage by number of grains.

After the slides were stained, it was possible to identify the principal constituents by the following characteristics.

Quartz.—The quartz grains are very little affected by the staining operation and appear colorless and transparent.

Potash feldspar.—The potash feldspars are attacked by the hydrofluoric acid and are coated with a gelatinous film containing potassium salts. The potash reacts with the sodium cobaltinitrite to form a distinctive yellow precipitate that coats the grains.

Soda-lime feldspar.—The soda-lime feldspars are attacked by the hydrofluoric acid and are given a white opaque fine-grained slightly lustrous surface. The high-lime feldspars and the more altered grains are more deeply etched than the high-soda feldspars.

Chert.—Chert is readily attacked by the hydrofluoric acid and develops a deeply and irregularly etched surface. Although the chert is light gray or white

[2] Gabriel, A., and Cox, E. P., A staining method for the quantitative determination of certain rock minerals: Amer. Mineralogist, vol. 14, pp. 290-292, 1929.

and opaque like the soda-lime feldspars, it has a dull surface. It commonly occurs in wedge-shaped or splinter-like grains. Some grains are not easily differentiated from highly altered soda-lime feldspars.

Shale.—The fragments of fine-grained sedimentary rocks, which consist principally of clay, silt, very fine sand, and mica in variable proportions, are listed in the tables as "shale." The shale grains have a wide range in composition but the most abundant type is composed largely of silt grains in a matrix of clay. The treatment with hydrofluoric acid deeply etches the clay in the shale grains so that the silt and sand grains—mostly quartz—stand in relief. Some of the stained shale fragments are peppered with small, yellow and white, opaque grains, probably feldspar.

Heavy minerals.—Minerals with a specific gravity greater than that of bromoform (about 2.9) are commonly called "heavy minerals." Most of the heavy minerals in these sands are only slightly or not at all affected by the staining process, and as most of them are colored they are easily recognized on the slides. Some colorless heavy minerals may be confused with quartz in the rapid counting method, but as the entire amount of heavy minerals is usually less than 3 per cent this is not likely to cause an important error in the amount of quartz. Identification of most of the heavy minerals on the stained slides is possible but because of their variety and relative scarceness in the slides not enough grains could be counted to give an accurate figure. They were therefore all grouped together. The heavy minerals of a few typical sands were separated from the original samples, using bromoform, and then mounted in Canada balsam on a glass slide and studied with a petrographic microscope.

Other minerals.—Several minerals represented only by scattered grains, and a few grains which could not be readily identified, were counted as "others." Also in this category were mineral aggregates, principally fragments of igneous and metamorphic rocks, which occur on the coarser sieve sizes, mostly 28-mesh and coarser. These grains are frequently mixtures of quartz and feldspar. Aggregates which are almost entirely feldspar were counted as potash or soda-lime feldspar according to which predominated.

Limestone and dolomite.—The percentage of limestone and dolomite, together with generally less than 1.0 per cent acid-soluble iron oxide, is represented by the total amount soluble in hydrochloric acid, given under *Condition C* in table 2.

RELATION OF GRAIN SIZE AND COMPOSITION TO FLOTATION AND AGGLOMERATE TABLING

Recent experimental work by the U. S. Bureau of Mines[3] has demonstrated that the feldspar can be almost completely separated from the other constitutents in granite or pegmatite by froth flotation and agglomerate tabling.

Although it is not known that flotation and agglomerate tabling will ultimately be found to be the best methods for recovering feldspar from Illinois sands, these methods offer promise and therefore it is of interest to discuss briefly the grain size and mineral composition of the sands in relation to the experimental work on the recovery of feldspar from granite. Much of the data given is probably pertinent to other processes which might be used for removing the feldspar from the sand.

The problem of separating feldspar from natural sands is, in many respects, not greatly different from that of separating it from an artificial sand—such as a crushed pegmatite or granite. The crushed granite consists predominately of feldspar, 20 to 40 per cent quartz, and smaller quantities of mica, hornblende, magnetite, and other comparatively rare minerals. In the sands quartz predominates, feldspar is 15 to 25 per cent, mica is rare, but the other constituents of the granite are present in small amounts.

[3] O'Meara, R. G., Norman, J. E., and Hammond, W. E., Froth flotation and agglomerate tabling of feldspars: Am. Ceramic Soc. Bull., vol. 18, pp. 286-292. 1939.

Experimental work is needed to demonstrate that the procedure used in the separation of the feldspars from the crushed granite is applicable to the natural sands. The Bureau of Mines found that feldspar-quartz mixtures from different mines do not always behave the same in flotation and agglomerate tabling, probably because of differences produced by weathering.[4] The surfaces of the feldspar grains in the sands may be more weathered than those in some granites and this may be of significance in relation to processing.

Grain Size

Commercial specifications for feldspar call for material as coarse as 20-mesh, and the Bureau of Mines found that the feldspar finer than 48-mesh could be separated by froth flotation and the feldspar between 48-mesh and 20-mesh could be separated by agglomerate tabling. Many of the Illinois sands adequately cover this range of grain size, and the oversize of coarser sands could be crushed to pass 20-mesh.

The 20-mesh grade, used by the glass industry, is produced by crushing to give the maximum amount of coarse material, but it has a range in grain size from 20-mesh to a fine powder. Although largely retained on 100-mesh, the 20-mesh grade contains powder which, partly because it makes dust, is considered objectionable. Feldspar produced entirely by froth flotation from Illinois sands would contain little feldspar coarser than 48-mesh, it would contain comparatively little material passing 100-mesh, almost none passing 200-mesh, and it would be free of powder. If this product is satisfactory for the glass trade it would not be necessary to use agglomerate tabling.

If only froth flotation is used it would be advantageous to develop deposits of sand finer than 48-mesh, especially as the fine-grained deposits in any large sand area usually contain slightly more feldspar than the coarser sands. Illinois contains deposits of dune and river sands which are finer than 48-mesh, although generally these types of deposits contain some sand coarser than 48-mesh. If the coarser sands are used, the material retained on 48-mesh might be crushed to pass 48-mesh.

If feldspar coarser than 48-mesh is required agglomerate tabling alone might be used. Some deposits contain as much as 80 per cent sand between 20- and 48-mesh.

The material finer than 270-mesh usually forms a small percentage of the sands. It contains much clay and comparatively little feldspar and would probably be washed out in conditioning the sand for flotation. It may also be desirable to wash out the 150-mesh and 200-mesh fractions in those sands which do not contain a large amount of these fractions, because these fractions contain a relatively large percentage of heavy minerals. The finer-grained material also contains a higher percentage of iron oxide than the coarser material.

The analyses show that in most sands the chert, shale, and aggregates are concentrated in the coarsest fractions, and it may be desirable to remove these fractions by screening. This screening may not be needed if the chert, shale, and aggregates remain with the quartz when the feldspar is separated and separation from the quartz is not desired.

Mineral Composition

As the flotation of feldspar is made in an acidic reagent,[5] the noncalcareous sands are probably the more favorable for this process. Because of the large quantities of calcareous sands available, a number of samples were studied to determine the amounts and distribution of the carbonate grains and to see if such sands offered any special advantages which might justify removing the carbonates. It was found that, in general, the greater the amount of carbonates the smaller the amount of feldspar, and consequently the highly calcareous deposits contain comparatively little feldspar. In many samples the distribution of the carbonates is such that it can be materially reduced by removing the coarse fractions. Possibly the carbonate con-

[4] Op. cit., p. 289.

[5] O'Meara, R. G., Norman, J. E., and Hammond, W. E., Op. cit. p. 288.

tent of some very slightly calcareous sands is so low that an excessive amount of flotation reagents would not be required to float the feldspar, but it seems probable that most calcareous sands would have to be processed to remove the carbonates before flotation of the feldspar.

As previously noted the feldspar grains appear to contain internally as little iron oxide as the present commercial feldspars, so that the problem of producing a low-iron feldspar is largely one of removing the iron oxide stain, which commonly occurs as a thin coating on the grains, and of separating other iron-bearing minerals. The noncalcareous dune sands commonly contain more iron oxide stain than the other sands, some of which are almost white. Much of the iron oxide stain can probably be removed by abrasion.

Iron oxide also occurs in the sands in grains of magnetite, ilmenite, limonite, hornblende, and augite, mostly in the finest sieve fractions. These minerals can possibly be separated from the quartz and feldspar magnetically or by some mechanical process depending on their relatively high specific gravity.

In the dune sands the potash and soda-lime feldspar are about equally abundant, but in the other types of sands the soda-lime feldspar predominates, commonly in ratios of 2:1 or 3:1. The production of a feldspar with a high soda-lime content might be desirable because of the lower fusion point of the soda-lime feldspar. On the other hand a high-potash content is desirable for certain kinds of glass.

SELECTION OF DEPOSITS

Development of a feldspar industry in Illinois must await demonstration that feldspar can be economically separated from the sands on a commercial scale. After this is achieved, selection of specific deposits for development will require the consideration of many factors, such as the location of the deposit in relation to markets and transportation, the adaptability of the deposit to the process to be used, the percentage of feldspar and its quality when separated, the cost of the land, and the extent, thickness, and overburden of the deposits.

In the selection of deposits the amount of feldspar is obviously an important consideration. Because the samples tested in the present investigation were of necessity distributed among many deposits, it was not possible to sample individual deposits in sufficient detail to reveal their variations in feldspar content. With a few exceptions, how-

Table 3.—Approximate Percentage of Feldspar in Various Types of Illinois Sands

General location and type of deposit	Number of samples	Average per cent feldspar in samples tested
Mississippi River sands below East St. Louis	6	30
Glacial outwash sand in Mississippi Valley	4	22
Fine-grained dune sand in Kankakee, Havana, and Chicago areas	14	21
Mississippi River sands above East St. Louis	7	21
Medium- and coarse-grained dune sand in Savanna and Oquawka areas	10	20
Medium- and coarse-grained dune sand in Kankakee, Havana, and west part of the Prophetstown areas	18	18
Wabash River sand	2	18
Dune sand in Lacon area	2	16
Lake Michigan lake and beach sand	4	14
Ohio River sand	4	14
Illinois River sand	3	10
Dune sand in Rockford and east part of Prophetstown areas	6	9
Calcareous glacial outwash sands and gravels	20	1-15

ever, the data available about each of the types of deposits are sufficiently consistent to permit a rough comparison of their relative feldspar contents (table 3). The variability of the feldspar within the deposits is probably such that differences of one or two per cent between different deposits are probably not significant.

Selection of a deposit will also in large part depend on the character of sand that is best adapted to the processing system to be used. Grain size as related to processing and trade requirements and the relative cost of processing calcareous and noncalcareous sand may be as important as the total percentage of feldspar, especially as many of the deposits differ only slightly in feldspar content. Some of the variations of the major deposits in grain size and composition are summarized in table 4. The locations are by map-areas described later (pp. 26-52).

Table 4.—Guide to the Selection of Illinois Sand Deposits Based on Variations in Composition and Grain Size

Characteristics	Type of deposit
Noncalcareous sand	
—48-mesh	Dune sand in Kankakee and Havana areas Possibly Mississippi River sand, especially near East St. Louis
—20-mesh (mostly 48-, 65-, and 100-mesh)	Dune sand in all areas Outwash sands in Savanna and Oquawka areas
+20-mesh material, or —20-mesh with high 28- and 35- mesh fractions	Outwash sand in Savanna and Oquawka areas Sand screened from gravel in Savanna area
Lowest possible iron-oxide content	Outwash sands in Savanna and Oquawka areas
Slightly calcareous sand (less than 5 per cent carbonates)	
—48-mesh	Mississippi River sand, especially south of East St. Louis
—20-mesh	Mississippi River sand Ohio River sand
Calcareous sands (over 5 per cent carbonates)	
—48-mesh	Lower parts of some sand dunes—probably can be used only with overlying noncalcareous sand—in Kankakee and Havana areas Mississippi River sand, especially south of East St. Louis (mostly less than 5 per cent carbonates)
—20-mesh	Lake Michigan beach and lake sand in Chicago area Lower parts of some sand dunes—probably can be used only with overlying noncalcareous sand—in Kankakee, Lacon, Havana, and Prophetstown area Illinois River sand Wabash River sand Sand screened from gravel deposits except along Mississippi Valley

TYPES OF DEPOSITS

The sand deposits of Illinois differ in composition and in manner of occurrence. Their variations result from differences in the sources of the sand grains and differences in the ways in which they were transported to and deposited at the places where they now occur. Most of the sands are composed largely of quartz, but some feldspar is present in all of them. These minerals were formed originally in igneous rocks, which on the average contain about 60 per cent feldspar and about 12 per cent quartz. They were freed from the igneous rocks by weathering and erosion and then transported and deposited by various processes, especially by rivers, glaciers, and wind. The relative amounts of quartz and feldspar in the sands vary because feldspar is more easily decomposed by chemical weathering, is softer, and has much better cleavage and therefore breaks and wears more readily. As the deposits of similar origin have many characteristics in common they are discussed together as "types." These types may be classified as follows:

Glacial outwash.—Most of Illinois was covered by glaciers during the Pleistocene period or "Ice Age". These glaciers transported great quantities of rock debris, some of which was sorted by the glacial melt-waters and laid down in gravel, sand, silt, and clay deposits.

Dune deposits.—Many of the large deposits of glacial sand and gravel are overlain by dunes of sand which was blown from the glacial deposits by the wind.

River deposits.—The present rivers transport large quantities of sand and gravel which they temporarily deposit in bars along their channels, on the inside of curves, behind jetties, and, during floods, on the floodplains. Much of the material carried by the rivers is derived from the glacial deposits by erosion.

Lake deposits—Large deposits of sand have been formed in Lake Michigan and along the beach of the lake by waves and currents. The sand is mostly derived from the glacial deposits.

Preglacial sand and gravel.—Extreme southern Illinois contains extensive deposits of sand and gravel which were formed during the Cretaceous and Tertiary periods and are older than the glacial deposits but are not consolidated like the bedrock formations.

Sandstones.—The sandstones are consolidated sand deposits. The bedrock formations of Illinois contain many sandstone formations.

The characters of the various types of sand deposits are discussed below.

Dune Sand

Illinois contains several large sand dune areas each of which contains hundreds of dunes. Many of the dunes have the shape characteristic of hills of wind-blown sand, namely gentle windward slopes and steep leeward slopes, but in some areas the dunes have long been inactive and because of slumping and erosion show only roughly the distinctive dune shape. The principal dune areas (fig. 1) are in Kankakee Valley, in Illinois Valley between Peoria and Beardstown, in Rock River Valley below Dixon, and in Mississippi Valley near Savanna, Fulton, and Oquawka. These as well as other smaller areas of dunes occur principally along the major valleys on large terraces of outwash sands and gravels, but locally they occur on the bluffs and adjoining highlands east of the terraces. In the latter areas they overlie glacial till or wind-blown silt (loess). On the terraces the dune sand usually grades into the underlying water-laid sand which is distinguished only by the presence of scattered pebbles or beds of coarse sand.

Thickness.—The thickness of the dune sand is usually about equal to the height of the dune. Exceptions occur (1) where the dunes are closely grouped in ridges and the wind-blown sands extend below the base of the dunes, (2) where the blow-outs between the dunes extend into the water-laid materials so that only the upper part of the dunes are wind-blown sand, and (3) where the wind-blown sand covers the surface of bars or low rounded hills of water-laid sand. In most dune areas the dune sand thins to a trace at the margin of the dunes, and the sand underlying the flats between the dunes is water-laid. However, some of the flats are the floors of extinct lakes and are underlain by silt, clay, peat, or muck. In most of the major areas some dunes are 50 to 75 feet high, and dunes 25 to 50 feet high are common.

Overburden.—Most of the dunes are covered with vegetation but there are usually a few blow-outs where the sand is uncovered, and adjacent to them are small dunes of bare sand. In the areas covered by vegetation the dune sand usually has a cover of 6 inches to 1 foot of dark brown silty sandy soil overlying 1 to 3 feet of silty sand or sandy silt which grades from very clayey and silty at the top to the typical dune sand at the base. Many of the dunes are forested or covered by thickets, and some now free of trees were formerly forested. As a result the roots of trees and shrubs are locally abundant in the upper 5 to 10 feet of sand.

Grain size.—Although the sands in adjacent dunes usually have about the same grain size, there are noticeable differences in grain size between dunes in widely separated parts of the larger areas. Sieve tests of the coarser-grained dune sands show that the greatest percentage of grains usually falls in the 35- to 48-mesh fraction, and in the finer-grained sands the greatest percentage falls in the 65- to 100-mesh fraction.

About half of the samples of dune sands studied (table 2) have a greater percentage of grains in the 65- to 100-mesh fraction than in any other fraction. In the remainder the greatest percentage falls in the 35- to 48-mesh or the 48- to 65-mesh fractions, about equally divided. Dunes on the upland areas are generally composed of finer-grained sand than those on the adjacent terraces.

The dune sands are well sorted and usually have 65 per cent or more retained on two adjacent sieves.

The dune sands contain on the average about 2 per cent of material finer than 270-mesh, mostly silt, but many contain less than 1 per cent. Samples which represent only the upper few feet of the deposits generally contain more silt than those representing the underlying sand, some as much as 12 per cent of material finer than 270-mesh.

Carbonates.—The upper 5 to 10 feet of all the dunes is noncalcareous, and in most areas the dunes appear to be composed almost entirely of noncalcareous sand. Locally the core of the dunes is calcareous. The calcareous dune sands commonly contain 5 to 10 per cent carbonates. In three samples tested the carbonates are uniformly more abundant in the finer sieve fractions, grading from 5 to 7 per cent in the coarser fractions to 25 to 30 per cent in the 150- to 200-mesh fraction.

Iron oxide.—Most of the dune sands are light brown because the grains of sand and particles of clay have a thin coating of limonite (hydrated iron oxide). Chemical analyses of several samples of the sand from the Kankakee area show that the iron oxide content is generally less than 1 per cent (table 5).

The upper 2 to 4 feet of sand usually contains more limonite than that below. A sample (SR-9) from the fresh sand exposed in the blow-out in a dune about three miles north of Coal City contains only 0.48 per cent iron oxide, whereas a sample (M-2) from the upper 7 feet of the deposit in the highest part of the same dune (omitting the upper two feet of silty sand and soil) contains 0.91 per cent iron oxide. These amounts include not only the limonite staining the grains but the iron oxide present in heavy minerals and as inclusions in the quartz grains.

Another sample (24) from the Coal City area, representing about 30 feet of sand, contains 0.65 per cent ferric oxide. Digesting the sand in hydrochloric acid lowered the ferric oxide to 0.13 per cent, indicating that 0.52 per cent ferric oxide is present as limonite or other hydrated iron oxide and that the balance occurs in certain of the heavy minerals and in inclusions in the quartz grains.

TABLE 5.—CHEMICAL ANALYSES OF DUNE SANDS

Sample No.[a]:	17	19	20	24	SR-9	M-2
SiO_2		89.88		92.37	93.7	91.37
TiO_2		0.25		0.14		0.22
Al_2O_3		4.57		3.28	3.94	3.63
Fe_2O_3	1.00	1.12	0.82	0.65	0.48	0.99
MgO		0.29		0.21	0.29	0.25
CaO		0.65		0.53	0.42	0.51
Na_2O		0.76		0.60	1.18	0.55
K_2O		1.83		1.49	0.51	1.50
H_2O+						
H_2O-		0.09		0.06	0.05	0.04
CO_2		0.19		0.15		0.50
Loss on ignition		0.54		0.44	0.22	0.60
Total[b]		99.89		99.71	100.11	99.61

a. Locations of samples 17, 19, 20, and 24 are given in table 1. Sample SR-9 was collected from sand exposed in a blow-out in NE. cor. SE. ¼ NE. ¼ sec. 24, T. 33 N., R. 8 E. (Grundy County). Sample M-2 was collected from a small pit in the top of the same dune as sample SR-9 and represents 7 feet of sand omitting the upper 2 feet of soil.
b. H_2O- and CO_2 are not included in total.

Another portion of the crude sample 24, from which the 4 per cent of material finer than 100-mesh was screened, contains 0.58 per cent ferric oxide, showing that the finer material contains a higher percentage of ferric oxide.

In many deposits the upper 2 to 4 feet of sand is dark brown, the color gradually becoming lighter toward the base of the zone. Below that some deposits contain irregular wavy bands of light and brown sand, the brown bands ranging from 1 to 4 inches thick and being separated by a few inches to a foot or more of light-colored sand. The dark bands appear to be slightly more silty than the light bands but in general there is little textural difference. When dry the dark bands become comparatively hard. The more recently formed sand dunes do not have this banding.

Quartz.—The average quartz content of the dune sands is 75 per cent, most of the sands containing 70 to 80 per cent quartz. The percentage of quartz varies in the different sieve fractions of each sand. Usually the maximum amount is in the 35- to 48-mesh fraction of the coarser-grained sands and in the 48- to 65-mesh fraction of the finer-grained sands. The decrease in the amount of quartz in the coarser fractions results from the rapid increase in abundance of shale, chert, and aggregates in these sizes. In the coarsest fraction the quartz may be as low as 50 per cent. The decrease in the amount of quartz in the finer fractions results from the increase of feldspar and heavy minerals.

Most of the quartz grains are colorless and clear. They are usually coated with a thin film of limonite. Some quartz grains contain small black inclusions of magnetite and consequently are included in extractions of the magnetic minerals. As a whole, the quartz grains are subangular but the smaller grains are predominately angular and many of the larger grains are well rounded.

Feldspar.—Dune sands range in feldspar content between extremes of 8 and 29 per cent. The 47 samples of dune sand examined contained an average of 18 per cent feldspar. The analyses show that with few exceptions the amount of feldspar in each sample increases in the finer sieve fractions of the samples. The 35- to 48-mesh and coarser fractions commonly contain 10 to 18 per cent feldspar, the 48- to 65-mesh contains 12 to 20 per cent, the 65- to 100-mesh contains 16 to 25 per cent, and the 100- to 150-mesh and finer fractions contain 20 to 30 per cent. A few samples from the upper Rock River Valley are unusually low in feldspar and contain less than the above. The deposits of fine-grained sands have a higher feldspar content than the coarser-grained sands, especially when comparing the sands in any one area. Twenty-four samples which have the highest percentage of sand in the 65- to 100-mesh fraction contain an average of 20 per cent feldspar, 10 samples with the highest percentage in the 48- to 65-mesh fraction average 17 per cent feldspar, and 13 samples with the highest percentage in the 35- to 48-mesh fraction average 15 per cent feldspar. The coarser sieve fractions of the fine-grained sands contain a little less feldspar than the same sizes in the coarser-grained sands, but the higher total feldspar in the finer-grained sands results from the higher percentage of sand on the sieve sizes with higher feldspar content.

In most of the samples studied the feldspar is nearly uniformly divided between the potash and soda-lime feldspars, although when there is any difference the soda-lime feldspars are usually the more abundant. The grains of potash feldspar are mostly clear and glassy and only a small percentage are clouded with alteration products. Many of the grains of soda-lime feldspar are also clear but a large proportion of them are cloudy and many are opaque and considerably altered. There is no readily apparent difference in the extent of alteration of the feldspar in the calcareous sands and in the noncalcareous sands overlying them. It appears therefore that the alteration of the soda-lime feldspars was accomplished previous to accumulation in the dunes.

Shale.—Most of the dune sands contain 2 to 3 per cent shale, but some samples contain less than 1 per cent and one sample contained 7 per cent. The shale is most abundant in the coarse fractions of the samples. The amount almost invariably decreases uniformly in successively finer sieve fractions and very little shale occurs in the sand finer than 100-mesh.

Chert.—Chert is present in nearly all the dune sands. It usually totals less than 1 per cent, but one sample contains 3 per cent. The chert is almost entirely in the coarser fractions of the sand. Although chert may comprise as much as 10 to 15 per cent of the material coarser than 28-mesh, material of this size usually forms less than 5 per cent of the coarsest-grained dune sands. Most of the chert is in the fractions coarser than 48-mesh, and the amount decreases progressively in the fine sizes, decreasing more sharply than does the amount of shale. Only a few chert grains occur in the 65- to 100-mesh fractions, and they are rare in the finer fractions.

Heavy minerals.—Most dune sands contain 1 to 2 per cent, rarely as much as 4 per cent, heavy minerals by weight. About half the heavy minerals separated from two samples from the Havana area are black opaque metallic grains, mostly ilmenite and magnetite, the former predominating. The mineral analyses of the heavy minerals separated from two samples are as follows:

Mineral	Per cent by weight	
	Sample 42	Sample 44
Ilmenite	30	44
Magnetite	20	12
Amphiboles and pyroxenes	30	26
Garnet	10	8
Light-colored aggregates		3
Zircon	1	3
Epidote	3	1
Rutile		1
Leucoxene	1	
Tourmaline	1	
Corundum	1	
Titanite	1	
Leucoxene, chlorite, tourmaline, others		2
Kyanite, topaz, apatite, rutile, others	2	

Although the percentages of the minerals were determined by counting grains, they were converted to per cent by weight on the basis of the average specific gravity of the mineral or the mineral group. The percentages are only approximate because of a considerable variation in grain size. The zircon and most of the epidote grains are very small, and most of the amphibole, pyroxene, and garnet grains are relatively large. The ilmenite and magnetite grains vary in grain size but are mostly smaller than the amphibole, pyroxene, and garnet grains.

Two samples of the beach sands of glacial Lake Chicago, from which the overlying sand dunes have been derived, contain the following heavy minerals[6]: Near Evanston—hornblende is abundant; chlorite, epidote, garnet, hypersthene, magnetite, tourmaline, and zircon are common; augite, diopside, and staurolite are rare. Near Harvey—chlorite, garnet, and hornblende are abundant; hypersthene and magnetite are common; augite, diopside, epidote, tourmaline, and zircon are rare; corundum, enstatite, and rutile are very rare.

The heavy minerals are rarely more than a trace in the sand coarser than 65-mesh but the 65- to 100-mesh fraction commonly contains 1 to 3 per cent, the 100- to 150-mesh fraction contains 2 to 5 per cent, and that finer than 150-mesh contains more than 5 per cent. Although the coarser-grained sands usually have a larger amount of heavy minerals in the 48- to 65-mesh and the 65- to 100-mesh fractions than do the finer dune sands, the finer-grained sands have a greater total percentage of heavy minerals.

Others.—Because of the variety of unidentified grains, miscellaneous rare grains, and mineral aggregates, there is not a consistant increase or decrease in abundance of the grains classed as "others" through the different sieve fractions as there is in most of the minerals. Many sands contain 1 or 2 per cent of "other" grains. The material coarser than 28-mesh in the coarser-grained sands frequently contains 2 to 6 per cent of mineral aggregates (principally igneous and metamorphic rocks) which are included under "others."

Chemical composition.—The chemical analyses of four samples of dune sands in the Kankakee district (table 5, p. 17) show that alumina varies from 3.28 to 4.57 per cent. As the samples contain little clay and shale the analyses indicate a feldspar content of approximately 16 to 22 per cent, assuming the average alumina content of the feldspar is 20 per cent. This checks closely with the data obtained from the mineral analyses.

[6] Lamar, J. E., and Grim, R. E., Heavy minerals in Illinois sands and gravels of various ages: Jour. Sed. Petrology, vol. 7, pp. 78-83, 1937. The sample near Evanston was collected in the center sec. 33, T. 42 N., R. 13 E., that near Harvey in the NE. ¼ NW. ¼ NW ¼ sec. 4, T. 35 N., R. 14 E.

River Sand and Gravel

Mississippi, Illinois, Ohio, and Wabash rivers transport large quantities of sandy gravel and sand that is temporarily deposited in bars along their channels and on their floodplains. The actual river beds do not consist entirely or continuously of sand; extensive areas consist of silt or silty clay. Bars of sand and gravel in the river beds are commonly covered with a few inches of silt. At low water many large sand flats are exposed, especially along Mississippi River where bars more than a mile long and one-fourth mile wide are common. Jetties have been built at many places along the rivers to maintain a navigable depth in the main channel, and enormous quantities of sand have accumulated behind the jetties. Some of these deposits are exposed at low water but many of them are now continuously submerged by ponding of the rivers behind dams.

Thickness.—Some of the sand deposits in the rivers are more than 50 feet thick in places. Because of the varying currents in the river, the grain size of the sand deposited frequently changes so that the deposits probably do not contain a great thickness of sand of uniform grain size at one place. Although the sand on the surface of some large bars exposed at low water is comparatively uniform in grain size, usually not more than a foot or two of this sand is exposed. As much as 10 feet of uniform sand has been observed.

The sand in bars on the floodplains is usually thin. The floodplain deposits locally contain a considerable thickness of sand and gravel, but these are usually lenticular and are interbedded with silt.

Overburden.—The bars along the rivers usually have no overburden, but any bar may be covered with silt during the receding stage of a flood.

Grain size.—Sand with almost any grain size desired can be found along the rivers. Most of the sand observed is medium or coarse-grained, usually contains some grains coarser than 8-mesh, and commonly the 35- to 48-mesh sieve fraction has the highest percentage (table 2). However, along Mississippi River south of Alton there are large bars in which the exposed sand has the highest percentage in the 65- to 100-mesh fraction.

The coarser-grained river sands have a wide range of grain-size distribution. Whereas 65 per cent of most of the dune sands is retained on two adjacent sieves, it requires three or four adjacent sieves to give a similar total for the river sands. The finer-grained river sands are better sorted and are similar in grain-size distribution to the dune sands.

The amount of material finer than 270-mesh is highly variable but some of the sand is almost free of this material. Nine of 13 samples of Mississippi River sand contain less than 1 per cent of material finer than 270-mesh and average only 0.4 per cent. The other four samples, mostly very fine-grained sands, range up to 11.6 per cent finer than 270-mesh.

Carbonates.—Most of the river sands are slightly calcareous and some are highly calcareous. The samples of Illinois River sand contain 5, 10, and 12 per cent acid-soluble material, Wabash River sand 9 and 23 per cent, and Ohio River sand 3 and 4 per cent. One sample of Ohio River sand was noncalcareous. Most of the Mississippi River samples contain 1 to 2 per cent acid-soluble material but several samples are not calcareous. The coarse sieve fractions of the river sands contain the highest amount of carbonates, as much as 30 per cent in the more calcareous samples, but the amount decreases on successively finer sieves to a minimum on the sieve fraction with the highest percentage of sand or on the size immediately below it. There is usually a slight increase in carbonates in the finer sieve sizes.

Iron oxide.—The river sands are mostly lighter gray in color and apparently have little iron oxide stain on the surface of the grains. Some of the heavy minerals consist of or contain iron oxide, but the quantity in heavy minerals is probably less than 1 per cent at most places. The river sands contain less iron oxide stain on the grains but more in heavy minerals than the dune sands.

Quartz.—The total quartz content varies from 50 to 80 per cent. The greatest percentage of quartz is usually in the 35- to 48- or 48- to 65-mesh fractions, decreasing rapidly in the coarser fractions because of the increase in shale, chert, and aggregates, and decreasing slightly in the finer fractions because of the increase in feldspar and heavy minerals. The quartz is mostly clear and subangular.

Feldspar.—The average feldspar content of the river sands tested is 21 per cent but the sands of different rivers differ in feldspar content. The Illinois River sands average 10 per cent; Ohio River sands, 15 per cent; Wabash River sands, 18 per cent; and Mississippi River sands, 25 per cent. The sands with the highest feldspar content were found in Mississippi River south of East St. Louis, where three samples contain 32 to 34 per cent feldspar. In most of the sands there is about twice as much soda-lime feldspar as potash feldspar. In many sands the amount of potash feldspar in the various sieve fractions is fairly uniform, although usually there is a slight decrease in the amount in the finer fractions. In the coarser-grained sands the soda-lime feldspars usually occur in fairly uniform amounts in the 28- to 35-mesh, 35- to 48-mesh, and 48- to 65-mesh fractions, which comprise the bulk of the samples, but both the coarser and finer fractions contain a higher amount of soda-lime feldspar. The finer-grained sands as a whole contain a higher percentage of feldspar than the coarser-grained.

Shale.—The river sands all contain some shale, commonly 2 to 4 per cent but locally as much as 10 per cent. Most of the shale occurs in the coarser fractions.

Chert.—Chert is present in all the river sands but in more variable quantities than the shale. The range is from a trace to 7 per cent with the average about 2 per cent. Chert occurs mostly in the coarse fractions.

Heavy minerals.—Most of the coarse- and medium-grained river sands contain less than 1½ per cent heavy minerals, but the fine-grained sands contain 2 to 4 per cent.

Other minerals.—The river sands usually contain 2 to 10 per cent of variable material classified as "others." In general, the river sands contain a slightly higher amount of "other" grains than the dune sands.

Outwash Sand and Gravel

During the Pleistocene or "Glacial" period most of Illinois was covered by glaciers. As the glaciers melted the melt-water was concentrated into streams that carried rock materials that had been incorporated in the glaciers and later deposited them in or below the ice, in plains along the ice front, or in valleys leading away from the ice. The coarse-grained materials were mostly deposited near the ice, the finer-grained materials at greater distances. These deposits as a group are called "outwash" deposits. Large outwash deposits of sand and gravel are especially common in the north part of the State (fig. 1) and also in the major valleys along which the glacial rivers carried sand and gravel many miles from the ice front. Most of the glacial-river deposits now occur in terraces at various levels above the present rivers.

Thickness.—Glacial outwash deposits vary from a few inches to more than 200 feet thick. In the large terraces along the major valleys they commonly extend below the present river levels and are more than 100 feet thick at many places.

Overburden.—Many large outwash deposits have an overburden of silt and soil from 1 to 5 feet thick. Some deposits locally have an overburden of dune sand and others have a thick cover of glacial clay and silt (till).

Grain size.—The outwash deposits vary in grain size from clay to coarse gravel. Some large outwash deposits are composed almost entirely of sand, but most of the sand deposits contain some pebbles and usually beds of gravel. All gravel deposits contain a considerable amount of sand mixed with the pebbles, and many of them contain about 50 per cent of sand.

As the sand might be easily screened from the gravel deposits and as some gravel deposits being worked have an excess of sand which is washed back into the pits, several samples of gravel representing outwash of different glaciers were included in the study to determine their feldspar content. Many important commercial deposits were not sampled but the samples tested (table 2) represent the major types of deposits of different age and origin. Because of the comparatively small size of the samples collected it is believed that the amount of material coarser than 8-mesh as reported is probably somewhat low for most of the gravel deposits.

Carbonates.—The samples collected from outwash deposits in terraces along Mississippi Valley are noncalcareous, and the material coarser than 8-mesh consists almost entirely of igneous and metamorphic rocks with some quartz, siltstone, and sandstone. Elsewhere in Illinois the glacial outwash is nearly all calcareous, and the material coarser than 8-mesh consists largely of limestone and dolomite with small amounts of igneous and metamorphic rock, sandstone, siltstone, and shale. In the portion of the samples between 8- and 270-mesh the per cent soluble in acid varies greatly but the amount is usually more than 10 per cent, is locally as much as 75 per cent, and averages 27 per cent in the 18 samples studied. In each sample the amount of carbonate decreases progressively from a maximum in the coarser sand to a minimum usually in the 48- to 65-mesh or 65- to 100-mesh fractions and then increases in the finer sand. By screening out both the finer and coarser fractions the average amount in the sand could be materially reduced. Generally the coarser-grained sands have a higher carbonate content than the medium- and fine-grained sands. Very fine-grained sands are frequently highly calcareous. This gradation results from the concentration of much of the quartz in its original source in the grain sizes between 20- and 100-mesh, causing the quartz sand to dilute the limestone and dolomite grains in this grain size.

Quartz.—Many outwash sands contain 40 to 70 per cent quartz but the very coarse-grained sands and the sand washed from gravels contain less. The greatest percentage of quartz is usually in the 35- to 48-mesh or 48- to 65-mesh fractions. The outwash sands contain less quartz than the dune and river sands because of the greater percentage of carbonates.

Feldspar.—The amount of feldspar in the calcareous outwash deposits is highly variable because of variations in the amount of carbonates and in the amount of materials coarser than 8-mesh which contain little feldspar. Most of the sand deposits contain 10 to 15 per cent feldspar. Some of the gravel deposits as a whole contain as little as 1 per cent feldspar, considering only the feldspar in the 8- to 270-mesh fraction as recoverable, and most of them contain less than 10 per cent feldspar. However, the 8- to 270-mesh material itself contains an average of 12 per cent feldspar. When the acid-soluble materials are removed from this fraction the remaining material contains 12 to 23 per cent feldspar, averaging 18 per cent. Therefore it appears that the outwash and dune sands have about the same feldspar content, comparing noncalcareous material of comparable grain size.

The noncalcareous outwash deposits along Mississippi Valley contain more feldspar than the other outwash deposits, four samples containing 21 to 23 per cent feldspar.

The outwash sands commonly contain 2 or 3 times as much soda-lime feldspar as potash feldspar although in a few samples they are about equal. The amount of potash feldspar commonly increases in the finer sieve fractions. The amount of soda-lime feldspar is more variable but commonly is lowest in the 28- to 35-mesh, 35- to 48-mesh, or 48- to 65-mesh fractions, increasing in abundance in both finer and coarser fractions. In the very coarse-grained sands the amount is usually slightly reduced in the coarsest fractions because of the abundance of aggregates.

Shale.—The outwash deposits commonly contain 2 to 10 per cent shale, most of which occurs in the coarse fractions.

Chert.—Chert commonly forms 1 to 5 per cent of the outwash deposits. Most of the chert is retained on the 28-mesh and coarser fractions. The outwash deposits along Mississippi Valley contain little chert.

Heavy minerals.—Most of the outwash deposits contain less than 1 per cent heavy minerals. The heavy minerals are irregularly distributed and locally streaks of sand are dark colored because of the abundance of heavy minerals. Most of the heavy minerals are in the sand finer than 65-mesh. A study[7] of the heavy minerals from many outwash deposits indicates that the following minerals are locally abundant: Augite, garnet, hornblende, and magnetite. The common minerals include chlorite, diopside, epidote, hypersthene, tourmaline and zircon. Scattered grains of many other minerals are present locally.

Others.—The outwash deposits contain 1 to 5 per cent of grains classified as "others". They are mostly fragments of igneous and metamorphic rocks which are common in the coarse fractions.

Lake and Beach Sand and Gravel

Large deposits of beach and lake sands occur along and in Lake Michigan. The material ranges from gravel to fine sand.

The one sample of lake sand studied (Sample 1, table 2) is a calcareous pebbly sand containing 21 per cent coarser than 8-mesh. The 8- to 270-mesh fraction contains 11 per cent of acid-soluble material. The whole sample contains 14 per cent feldspar but the 8- to

[7] Lamar, J. E., and Grim, R. E. Heavy minerals in Illinois sands and gravels of various ages, Jour. Sed. Petrology, vol. 7, pp. 78-83, 1937.

270-mesh fraction contains 18 per cent feldspar, of which about two-thirds is soda-lime feldspar. The sample contains 8 per cent shale and 12 per cent chert which is considerably higher than in the outwash, river, and dune deposits sampled.

One of three samples of beach sand is a pebbly sand and the other two are medium-grained sand similar to dune sand in grain size. All are calcareous, varying from 7 to 19 per cent soluble in acid. The two medium-grained sands contain 11 and 16 per cent feldspar, and the 8- to 270-mesh fraction of the pebbly sand contains 14 per cent feldspar.

Another study of six samples of Illinois beach sands showed the heavy minerals vary from 1.4 to 7.5 per cent by weight.[8] The average mineral content of the six samples in per cent by number of grains is as follows:

Magnetite and ilmenite	40.9
Augite	24.9
Hornblende	12.1
Leucoxene, etc.	10.9
Garnet	5.5
Epidote	1.5
Diopside	1.0
Hypersthene	.8
Zircon	.8
Actinolite	.2
Staurolite	.2
Tourmaline	Tr
Titanite	Tr
Rutile	Tr
Kyanite	Tr
Biotite	Tr
Pyrite	Tr

In another study[9] one sample from the beach near Glencoe contains 1.4 per cent heavy minerals, and one from near Lake Bluff contains 9 per cent heavy minerals. In the sample from Glencoe hornblende and hypersthene are abundant; augite, diopside, epidote, garnet, and magnetite are common; olivine is rare, and rutile and tourmaline are very rare. In the sample from Lake Bluff augite, diopside, hypersthene, and magnetite are abundant; epidote, garnet, and hornblende are common; chlorite and enstatite are rare; and kyanite, rutile, staurolite, topaz, and zircon are very rare.

[8] Pettijohn, F. J. Petrography of the beach sands of southern Lake Michigan, Jour. Geol. vol. 39, pp. 432-455, 1931.

Preglacial Sand and Gravel

Large deposits of sand and gravel accumulated in the extreme southern part of Illinois during the Cretaceous and Tertiary periods (fig. 1). Four samples of these materials were examined. A sample of Eocene sand and two samples of Cretaceous sand contain only a few grains of soda-lime feldspar. One sample of "Lafayette" (Pliocene?) sand contains less than 1 per cent of potash feldspar and 2 to 3 per cent soda-lime feldspar. Because of the very low feldspar content of the samples examined, it is probable that the Cretaceous-Tertiary deposits may be ruled out as a commercial source of feldspar.

Sandstone

The bedrock formations of Illinois contain many beds of sandstone, and the presence of grains of feldspar in them has long been recognized. In the present study hand-samples of many formations were studied to determine the possibilities of these formations as a commercial source of feldspar. Samples of New Richmond, St. Peter, Glenwood, Bethel, Cypress, Hardinsburg, Degonia, and Lick Creek sandstones contain a few scattered grains of feldspar but in all of them feldspar is much less than 1 per cent. A sample of Makanda sandstone contains about 2 per cent feldspar, and several higher Pennsylvanian sandstones contain 2 to 15 per cent feldspar.

As the sandstones contain less feldspar than the sand deposits, they are probably not important as commercial sources of feldspar.

Glacial Till

Most of the area of Illinois that was covered by the glaciers is mantled with glacial till, a deposit of silty clay containing sand grains, pebbles, and boulders. As many of the deposits of till contain a considerable amount of sand, and as the different glaciers carried materials from different source areas, several samples of the sand washed from tills were examined to see if the deposits

[9] Lamar, J. E., and Grim, R. E., Heavy minerals in Illinois sands and gravels of various ages, Jour. Sed. Petrology vol. 7, pp. 78-83, 1937.

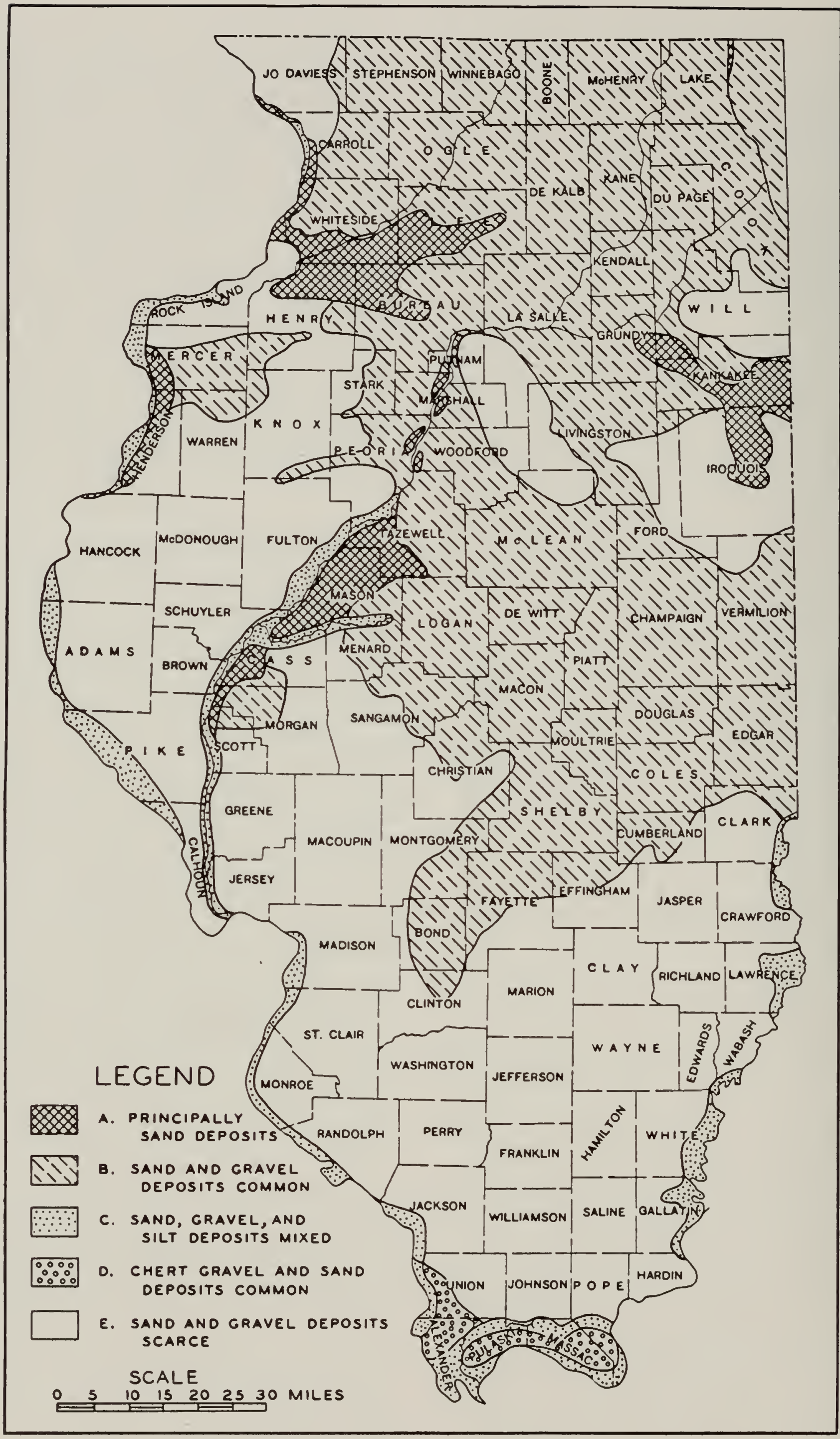

Fig. 1.—Sand and gravel areas of Illinois (excepting silica sand).

of any particular glacier contain an unusual concentration of feldspar. If so, the outwash sand and gravel deposits of that glacier might have a higher feldspar content than the other outwash deposits. Two samples of Illinoian tills (105, 106, tables 1, 2) and three of Wisconsin till (102-104) were examined. The 8- to 270-mesh fractions of the Illinoian till samples, acid-treated to remove carbonates, contain 15 and 17 per cent feldspar, and the same fractions of the Wisconsin till samples contain 15, 18, and 20 per cent feldspar. Although these data are too limited to be conclusive they suggest that the feldspar content of the tills is approximately the same.

Possible Advantages and Disadvantages of the Various Types

As it is uncertain what methods may be used in processing the sands and what chemical and grain-size specifications they may impose on the sand, only a general consideration of the advantages and disadvantages of the various types of deposits is given. The problem of disposal of the sand after the feldspar is removed, if the sand cannot be sold, is an important consideration which depends more on conditions at the individual deposit than on the type of deposit. If the waste sand is clean and fine-grained it may be easily blown about when dry and therefore require special handling in stock-piling. Deposits excavated from below water might have an advantage if the waste sand can be returned to the pit.

Some of the possible advantages and disadvantages of the various types are listed below:

DUNE SANDS

Possible advantages

- Noncalcareous
- Comparatively high feldspar content
- Uniform grain size
- Well-sorted
- Fine grain size
- Low clay content
- Large deposits
- Thin overburden
- Low-cost mining
- Areas mostly of relatively low agricultural value

Possible disadvantages

- Cores of dunes calcareous in some areas
- More iron oxide stain on grains than other types
- Clay dried on grains and more difficult to scrub off

RIVER SAND

Possible advantages

- High feldspar content
- High content of soda-lime feldspars
- Low iron oxide stain on grains
- Low clay content
- Clay not dried on grains and easily scrubbed off
- Large quantities of almost any desired grain size
- No overburden
- Production by low-cost dredging
- Mobility of operation if different grain size desired
- Large supply of water available for processing
- Low-cost water transportation
- Low original cost of sand
- Waste sand easily disposed of by returning to river

Possible disadvantages

- Slightly calcareous
- Variability of individual deposits in grain size
- Shifting of deposits during floods
- River water at times may be too muddy for use in process
- Intermittent operation because of ice and floods

OUTWASH SAND AND GRAVEL

Possible advantages

- Less iron oxide stain on grains than on noncalcareous dune sands
- Mississippi Valley deposits noncalcareous
- Mississippi Valley deposits have high feldspar content

Possible disadvantages

- Calcareous, except in Mississippi Valley
- Lower feldspar content, except in Mississippi Valley

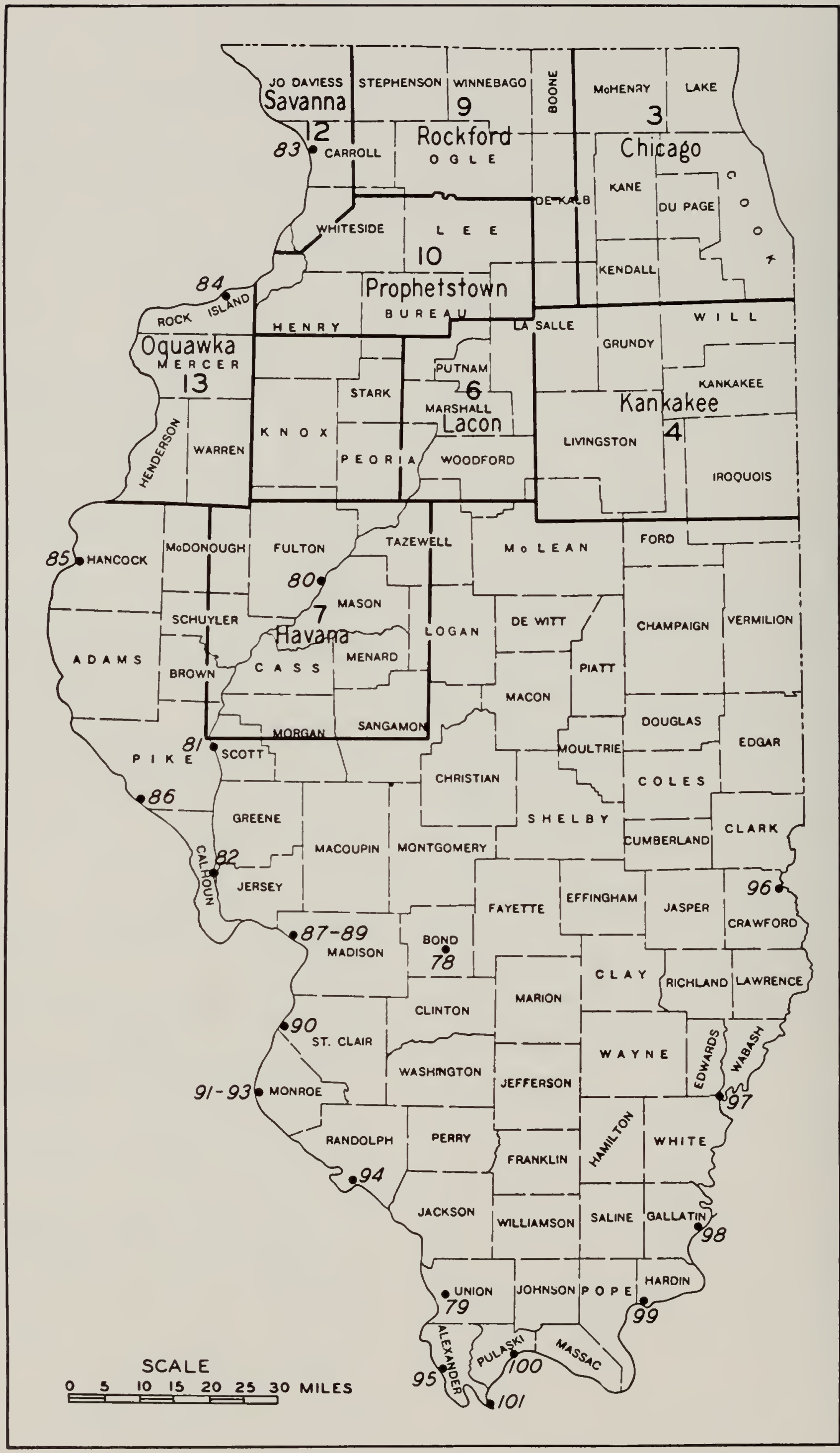

Fig. 2.—Locations of the map-areas, of samples collected outside the map-areas, and of samples from rivers.

Variable grain size
Thicker overburden than dune sands
Land usually more valuable than dune areas

LAKE AND BEACH SAND AND GRAVEL

Possible advantages

Less iron oxide stain on grains than dune sands
About same feldspar content as dune sands
Low clay content
Low original cost of sand
Production by low-cost dredging
Water available for processing
Proximity to Chicago industrial districts
Water transportation to lake ports

Possible disadvantages

Calcareous
Variable in grain size
Intermittent operation because of storms and ice

PREGLACIAL SANDS AND SANDSTONES

Disadvantage

Too low feldspar content

DESCRIPTION OF DEPOSITS

The most extensive deposits of sand and gravel in Illinois occur in the north part of the State. To show their general distribution the north part of the State was subdivided into the map-areas shown in fig. 2. Following is a brief description of the deposits in the map-areas and in the major rivers.

Chicago Area

The principal deposits of sand in the Chicago area occur in Lake Michigan and its beaches, in sand dunes and beach deposits along the shorelines of glacial Lake Chicago, and in outwash deposits which are widely distributed but especially abundant along DesPlaines, DuPage, and Fox valleys (fig. 3).

LAKE SAND

Large quantities of sand and gravel occur on the floor of Lake Michigan and material dredged from these deposits is extensively used in the building industry in Chicago. The one sample (1, tables 1, 2) of lake sand studied (p.....) is a calcareous pebbly sand containing 14 per cent feldspar. The deposits on the lake bottom are principally sand but they vary in grain size from sand to gravel. Seven samples collected on a line from near shore at Jackson Park to 8.1 miles out in the lake consist of material largely between 32- and 115-mesh, but within this range some of the samples have as much as 85 per cent finer than 60-mesh and some have only 25 per cent.[10]

BEACH SAND

Large deposits of sand occur in the beaches of Lake Michigan, especially north of Chicago, but because much of the beach is used for recreational and other purposes its availability as a source of sand is uncertain. As these sands are probably similar in composition to those which might be dredged from the lake a short distance off shore, samples from the beach at Zion City (2) and Glencoe (4) were studied. The sample from Zion City is a pebbly sand containing 12 per cent feldspar. After removing the material coarser than 8-mesh, the proportion of which is highly variable along the beach, the sand contains 14 per cent feldspar. The sample from the beach at Glencoe contains 16 per cent feldspar. A study[11] of six samples collected along the beach shows the sand is largely between 35- and 100-mesh in grain size, contains little fine sand and clay, and 10 to 15 per cent acid-soluble material. Between the present shore and the bluff north of Waukegan, in a belt one-half to one mile wide, many low ridges of sand occur along former shore lines of the lake. A sample (3) from one of these ridges near Zion City contains 11 per cent feldspar. This sample and one from the present beach at Zion were unusual in containing only 3 to 4 per cent potash feldspar. The

[10] Hough, Jack L. The mechanical composition of the deposits of southern Lake Michigan: University of Chicago, Thesis, 1934.

[11] Pettijohn, F. J. Petrography of the beach sands of Southern Lake Michigan: Jour. Geol. Vol. 39, pp. 432-455, 1931.

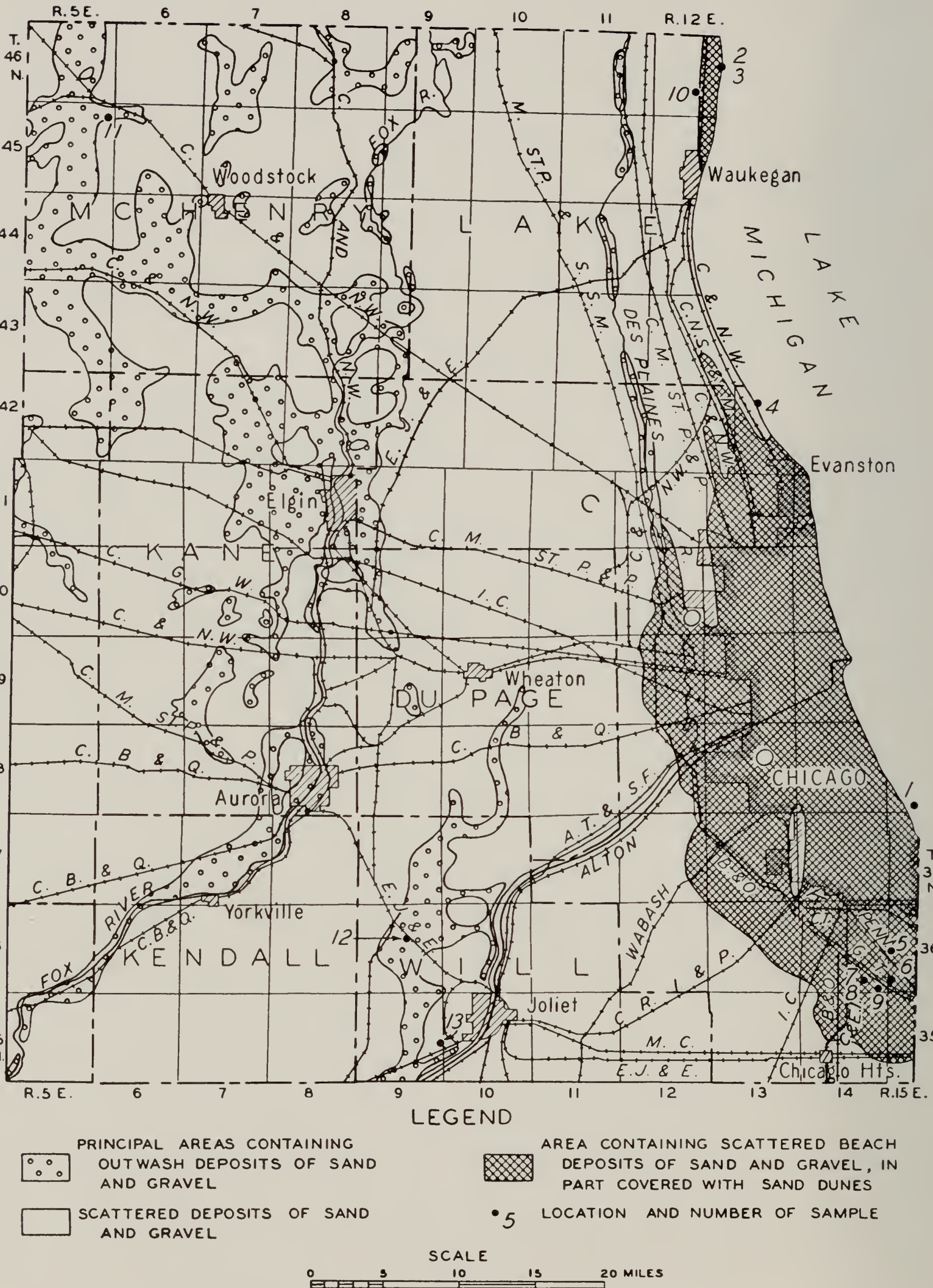

Fig. 3.—Sand and gravel deposits in the Chicago area.

distribution of the sand ridges in the area north of Waukegan is shown on the topographic map of the Waukegan quadrangle.[12]

DUNE SAND

Deposits of dune sand overlying beach sand occur at many places along old shorelines in the area formerly covered by ancient Lake Chicago.[13] Most of the deposits are now covered by the residential and industrial areas of Chicago and its neighboring cities and are not available for development. Probably the largest deposits still accessible occur south of Chicago near Lansing, but because of the relatively high value of the land in this area and the thinness of the deposits, it is not certain that they can be developed on a large scale as a source of feldspar.

Dune sand overlies beach sand in a ridge extending from Lansing west to Thornton along Ridge road. The ridge is shown on the Calumet City quadrangle map. Four samples (6-9) of the dune sand are medium to fine sand, mostly finer than 48-mesh with the maximum percentage on the 100-mesh sieve (one sample on 150-mesh). They contain 20 to 23 per cent feldspar, a percentage slightly higher than the average of all dune sands. The dune sand is generally only 3 to 5 feet thick below the higher part of the ridge. It overlies slightly coarser-grained sand. In the higher ridges the upper 7 to 10 feet of the deposits is generally noncalcareous but on the margin of the ridges calcareous sand is only 3 to 4 feet deep. The largest areas without buildings are west of the Grand Trunk Railroad at Lansing in secs. 35 and 36, T. 36 N., R. 14 E.

A sample (5) from another sand ridge about three miles north of Lansing contains 28 per cent feldspar, but the ridge has a paved road along its crest, and it is doubtful if a large-scale development could be undertaken in this area.

[12] The topographic maps may be obtained at 10 cents each from the State Geological Survey, Urbana, Illinois.
[13] Alden, W. C., U. S. Geol. Survey Geol. Atlas, Chicago folio (No. 81) 1902.
Bretz, J H. Geology of the Chicago Region, Pt. 1—General: Illinois State Geol. Survey Bull. 65, plate I, 1939.

OUTWASH SAND AND GRAVEL

Outwash deposits of gravel and sand are widely distributed (fig. 3) and of large size.[14] They are highly calcareous and consequently are relatively low in feldspar. Four samples (10-13) of outwash sand and gravel contain feldspar in amounts varying from 1 to 14 per cent, but after the acid-soluble materials are removed the 8- to 270-mesh fraction contains 16 to 23 per cent feldspar.

Kankakee Area

The Kankakee area (fig. 4) contains large deposits of dune sand and outwash sand and gravel.

DUNE SAND

In the Kankakee area, sand dunes occur principally in a broad terrace along Kankakee Valley, where they overlie glacial sand and gravel, and on the surface of a glacial lake bottom in Iroquois Valley, where they overlie glacial sands and silts. Because of the westerly winds some sand has been blown onto the upland east of the Iroquois Valley area.

The dunes are of all sizes and shapes. Many dunes southeast of Momence (fig. 5) are ridges elongated northwest to southeast and have a typical steep slope on the northeast or lee side and a comparatively gentle slope on the southwest or windward side. In some areas, as north of Watseka, the dunes are less regular in shape. The individual dunes are mostly grouped in more or less continuous ridges, in which there are 25 to 50 dunes in a square mile.

Where the dunes are closely grouped the sand is continuous from one dune to the other, but where the dunes are more scattered, and especially where they are separated by broad flat areas, the intervening areas may be underlain by water-laid sand or gravel, by lake deposits of silt or peat, by glacial till, or locally by bedrock.

[14] Bretz, J H., op. cit.
Fisher, D. J., Geology and mineral resources of the Joliet quadrangle: Illinois Geol. Survey Bull. 51, 1925.
Trowbridge, A. C., Geology and geography of the Wheaton quadrangle: Illinois Geol. Survey Bull. 19, 1912.

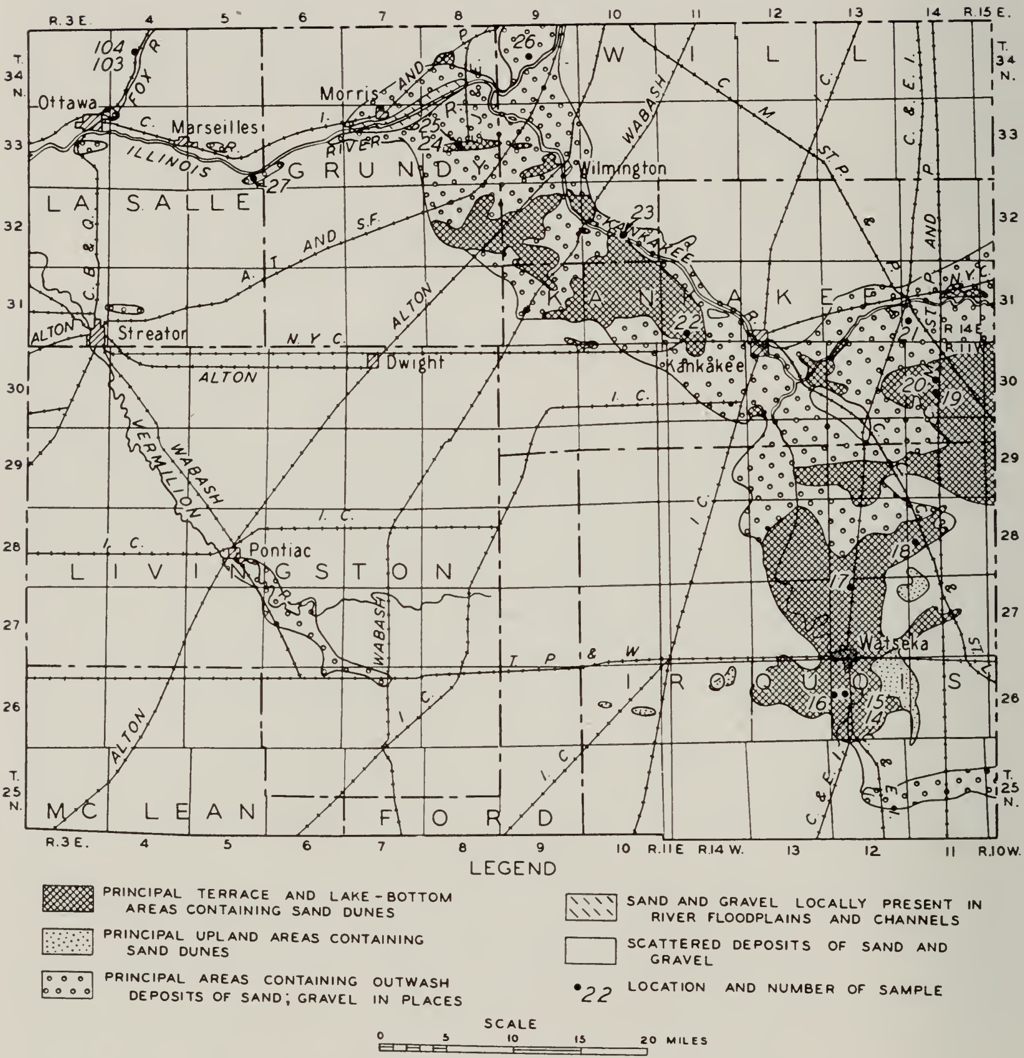

Fig. 4.—Sand and gravel deposits in the Kankakee area.

The location and size of many individual sand dunes is shown on the topographic maps of the Watseka, Momence, Kankakee, Herscher,[15] Wilmington, and Morris[16] quadrangles. As the topography of some of the glacial hills of silt and clay (till) is similar to that of the sand dunes, the dune areas may be differentiated on the topographic maps by comparing the maps with figure 4, or with the Soil Survey maps of Iroquois, Kankakee, Will, and Grundy counties.[17]

Thickness.—Dunes 15 to 25 feet are abundant and some dunes are 25 to 50 feet high. The dune sand is probably about as thick as the dunes are high, except that in the ridges of continuous dunes it may extend below the immediate base of the dunes. As the surface of the underlying water-laid sand is irregular the present topography is not an accurate guide to the thickness of the sand. However, over entire areas a mile square or larger the dune sand probably averages 10 feet or more thick.

Overburden.—The dune sand commonly has an overburden of 1 to 2 feet of soil and dark brownish-gray silty sand. Below this zone the upper 2 to 5 feet of sand is generally darker colored and slightly more clayey than that below, and part of this zone might also be removed as overburden if desirable to reduce the iron oxide content of the sand. Many of the dunes in this area are or have been forested, and roots are abundant in the upper few feet of these dunes.

Grain size.—In general the dune sands reflect grain-size variations of the underlying outwash deposits. In the southern part of the area near Watseka, where the outwash deposits were originally laid down in relatively quiet waters and are fine-grained, the dunes are mostly composed of finer-grained sand than they are a little farther north, near Hopkins Park. The Hopkins Park dune sand is in turn mostly finer-grained than the sand in the dunes along the main course of Kankakee Valley from Momence to Morris. In the Watseka area four samples of dune sand (14-17, tables 1, 2) are relatively fine-grained containing only about 2 per cent coarser than 48-mesh. Three samples (18-20) from the Hopkins Park area contain 5 to 20 per cent coarser than 48-mesh. Four samples (21-24) along Kankakee Valley contain 25 to 50 per cent coarser than 48-mesh, although finer-grained sands are known to occur locally in this area.

Composition.—In general the finer-grained sands have the highest feldspar content. The seven samples from the Hopkins Park and Watseka areas average 21 per cent feldspar, ranging from 18 to 24 per cent. The coarser-grained samples from Momence to Morris average 17 per cent feldspar, ranging from 15 to 19 per cent. Chemical analyses of several samples from this area are given in table 5 (p. 17), and are discussed on page 19.

Most of the sand exposed is noncalcareous but locally a little slightly calcareous sand is found near the base of the dunes. As the lower parts of the sand dunes are rarely exposed the occurrence of calcareous sand may be common. However, at least the upper 10 to 15 feet of many sand dunes is noncalcareous, and locally as much as 35 feet of noncalcareous sand was observed.

Size of deposits.—The quantity of dune sand in the area is enormous. For example, the dune area south of Momence and east of St. Anne in the southeast part of Kankakee County probably contains more than a billion tons of sand. However, in most of the dune areas many of the dunes are scattered or the deposits are thin so that the quantities available within half a mile of a possible plant site may not be sufficiently large to provide the reserve needed for a large-scale development. Locally, however, the dunes are more concentrated and the reserves are probably adequate. A few of the areas which appear to have large reserves are listed below.

(1) Along Chicago, Milwaukee, St. Paul and Pacific R. R. southeast of

[15] Athy, L. F., Geology and mineral resources of the Herscher quadrangle: Illinois Geol. Survey Bull. 55, 1928.

[16] Culver, H. E., Geology and mineral resources of the Morris quadrangle: Illinois Geol. Survey Bull. 43B (extract from Bull. 43), 1922.

[17] Obtainable from the University of Illinois, Agricultural Experiment Station, Urbana, Illinois.

Fig. 5.—Topographic map of a typical area of sand dunes in the Kankakee map-area. The northwest corner of the area is three miles south of Momence. (Part of the Momence quadrangle—contour interval 10 feet—scale shown by the land-sections which are approximately one mile square.)

Momence (fig. 5), especially in secs. 16, 21, 33, T. 30 N., R. 11 E. (Momence quadrangle). It is estimated that the dunes in the west half of sec. 33, all within half a mile of the railroad, contain at least 3 million tons of sand and perhaps more than twice that amount if the sand extends below the general level of the base of the dunes.

(2) Along Chicago and Eastern Illinois Railroad between Pitwood and Watseka (Watseka quadrangle) and also south of Watseka, especially in secs. 16, 17, 20, and 21, T. 26 N., R. 12 W.

(3) Along Cleveland, Cincinnati, Chicago and St. Louis Railroad one to two miles northwest of Donovan (Watseka quadrangle).

(4) Along New York Central Railroad west of Kankakee, in sec. 33, T. 31 N., R. 11 E., and secs. 4 and 5, T. 30 N., R. 14 W. (Kankakee quadrangle).

(5) Along Wabash Railroad near Custer Park and Ritchey, especially in sec. 18, T. 32 N., R. 10 E. (Herscher and Wilmington quadrangles).

(6) Along Alton Railroad between Godley and Braidwood (Herscher and Wilmington quadrangles).

(7) Along Elgin, Joliet, and Eastern Railroad north of Coal City, in secs. 15 and 22, T. 33 N., R. 8 E. (Morris quadrangle).

OUTWASH DEPOSITS

Large deposits of outwash sand occur in Kankakee Valley underlying the sand dunes and the areas between the dunes. The sand is generally coarser-grained and more variable in grain size than the dune sand and frequently is pebbly. Except where overlain by dune sand, the upper 4 to 6 feet is usually noncalcareous and stained brown with limonite. The underlying calcareous sand is mostly light gray but is locally light brown, especially near the top. These deposits probably contain nearly as much feldspar as the dune sands. One sample (25) from outwash sand underlying dune sand north of Coal City, contained 15 per cent feldspar. This sample was only slightly calcareous (1 per cent acid-soluble), but most of the unweathered outwash deposits are more calcareous. These sands underlie large areas along Kankakee Valley, especially near Momence, Kankakee, Essex, and Braidwood. If a sand coarser than that in the dunes is desired, these deposits are a possible source.

Many deposits of outwash sand occur along Illinois Valley, and a sample (27) of pebbly sand from near Seneca contains 13 per cent feldspar, but the 8- to 270 mesh fraction of the sand, after removing the 24 per cent acid-soluble material, contains 18 per cent feldspar.

DesPlaines and Illinois valleys contain large deposits of gravel. The one sample (26) tested contains unusually coarse sand which was highly calcareous (76 per cent acid-soluble) and contains only 4 per cent feldspar. Most of the gravel deposits contain finer-grained sand which is less calcareous and contains more feldspar.

LACON AREA

In the Lacon area (fig. 6) large deposits of dune sand overlie outwash deposits of sand and gravel which occur in large terraces along Illinois Valley. Other outwash deposits of sand and gravel are exposed along the valleys tributary to Illinois Valley and in the Illinois Valley bluffs.

DUNE SAND

Sand dunes occur on the terraces at Hennepin, Lacon, Chillicothe, and Spring Bay but do not occur on the terrace at Henry. The dune areas are smaller than those which occur farther up Illinois Valley (Kankakee area) and down the valley south of Peoria (Havana area) but each of the terraces contains several million tons of dune sand. The distribution of the individual dunes can be observed on the topographic maps of the Hennepin,[18] Lacon, Metamora, and Dunlap quadrangles and the Soil Survey maps of Bureau, Putnam, Marshall, Woodford, and Peoria counties.

[18] Cady, G. H., Geology and mineral resources of the Hennepin and LaSalle quadrangles: Illinois Geol. Survey Bull. 37, 1919.

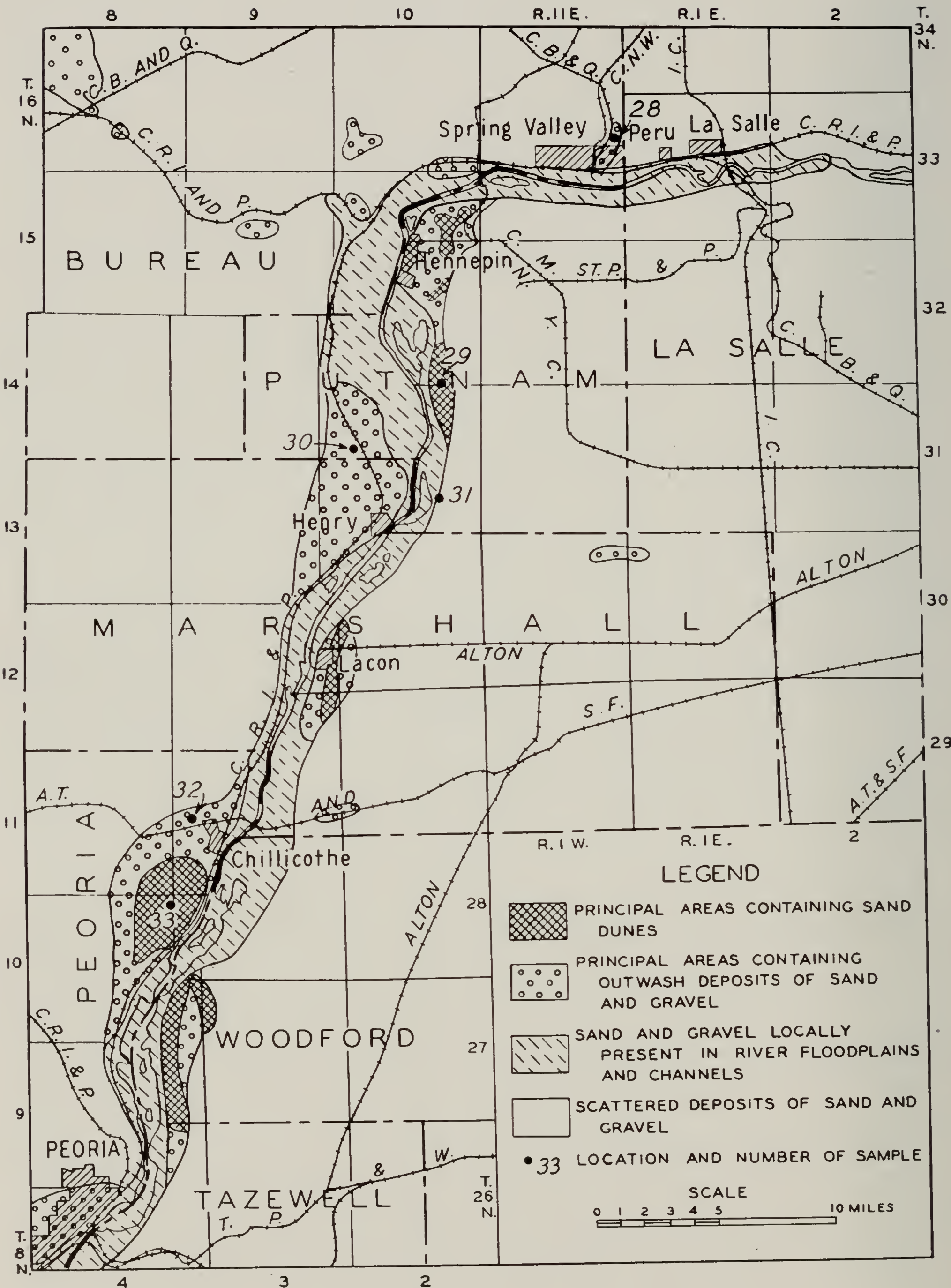

Fig. 6.—Sand and gravel deposits in the Lacon area.

Generally the dunes occur on a ridge along the central part of the terraces. On the Hennepin terrace they occur also along the bluffs. On the southern extension of the Hennepin terrace northeast of Henry almost the entire area is covered with dunes. On the Spring Bay terrace the dunes follow a central ridge, except that at both ends of the terrace they curve to the bluffs and extend up the bluffs onto the uplands.

Thickness.—On the Hennepin, Lacon, and Spring Bay terraces the individual dunes are mostly 10 to 20 feet high. Many dunes on the Chillicothe terrace are 20 to 30 feet high. The dunes are closely grouped in most of these areas so that dune sand is continuous from one dune to the next. The apparent thickness of the dune sand is frequently not the true thickness because of irregularities in the surface of the underlying sand, especially in places where the dunes occur on large bar-like ridges of outwash sand and on the slopes between high and low terraces.

Overburden.—Except in the relatively small areas of blowouts the dune sand has an overburden of 1 to 2 feet of soil and dark brown silty sand.

Grain size.—Most of the dune sands in this area are medium- and coarse-grained. A sample (29, tables 1, 2) from the Hennepin terrace contains 35 per cent coarser than 48-mesh, and one sample (33) from the Chilicothe terrace contains 75 per cent coarser than 48-mesh.

Composition.—The dune sands appear to contain a little less feldspar than the dunes in some other areas. A sample (29) from the Hennepin terrace contains 15 per cent feldspar, and one (33) from the Chillicothe terrace contains 16 per cent feldspar.

The dune sand is largely noncalcareous but locally the lower part is calcareous. Many exposures show that the noncalcareous sand is at least 5 to 10 feet thick.

Size of deposits.—The largest deposits of dune sand in the area are on the Chillicothe terrace mostly west and southwest of Rome near Chicago, Rock Island, and Pacific Railroad, especially in sec. 31, T. 11 N., R. 9 E., sec. 36, T. 11 N., R. 6 E., secs. 1 and 12, T. 10 N., R. 8 E., and sec. 6, T. 10 N., R. 9 E. (Dunlap quadrangle). The quantity of dune sand available is difficult to estimate because of the irregular top and bottom surfaces of the sand but it is probable that each of the sections listed above contains more than 5 million tons of dune sand.

OUTWASH DEPOSITS

The terraces along Illinois Valley are composed of outwash deposits of sand, pebbly sand, and gravel. Many borings on the terraces penetrate 100 to 125 feet of sand and gravel, and as the terraces cover many square miles the quantity is very large. The deposits are calcareous except for a thin weathered zone along the top. Because of the dilution produced by the abundance of carbonates they contain less feldspar than the dune sands. Some of the pebble-free sands contain as much as 15 per cent feldspar but the pebbly sands and gravels commonly contain less than 10 per cent feldspar.

A sample (30) of calcareous pebbly sand from the Henry terrace contains 7 per cent feldspar but the 8- to 270-mesh fraction contains 10 per cent feldspar and 31 per cent acid-soluble material. A sample (32) of fine-grained sand washed from the gravel in the Chillicothe terrace contains 15 per cent feldspar, and 8- to 270-mesh material (when free of 15 per cent acid-soluble material) contains 20 per cent feldspar. As this sample consists principally of the 100-, 150-, and 200-mesh material, it represents only a small proportion of the entire deposit.

A sample (28) of well-sorted medium-grained calcareous sand from an outwash deposit northeast of Spring Valley contains 12 per cent feldspar and 16 per cent acid-soluble material. A sample (31) representing extensive outwash deposits of gravel and sand exposed in the east bluffs of Illinois Valley east of Henry is a pebbly sand containing 10 per cent feldspar, but the 8- to 270-mesh fraction contains 14 per cent feldspar and 14 per cent acid-soluble material.

Havana Area

In the Havana area (fig. 7) sand dunes cover approximately 375 square miles of a broad terrace east of Illinois River. Dunes also occur on the east bluffs and the uplands east of Illinois Valley in an area of about 30 square miles, mostly in Mason but also in Cass and Scott counties. Dunes are also abundant in relatively small areas of the uplands adjacent to Sangamon Valley. In Illinois Valley the dune sand overlies outwash deposits mostly sand or pebbly sand but locally gravel. Large deposits of sand also occur in Illinois River, as described under river sand (p. 51).

DUNES

The sand dunes occur principally in ridges extending roughly northeast-southwest parallel to the general trend of the valley. Each ridge consists of hundreds of sand dunes varying widely in size and shape. The extremely rough topography of the area is shown in figure 8. The dunes mantle the surface of bars of outwash sand.

East of the terrace area some of the sand has been blown onto the uplands. The upland dunes are broad, low, and more scattered than those on the terraces. Between them loess and glacial till directly underlie the surface soil.

The distribution of the sand dunes is well shown on the topographic maps of the Peoria, Delavan, Manito, Havana, Beardstown, Chandlerville, Petersburg, Arenzville, Meredosia, and Griggsville quadrangles, and on the soil maps of Peoria, Tazewell, Mason, and Morgan counties.

Thickness.—The dune sand is generally as thick as the dunes are high, and on some of the major ridges the dune sand may extend below the topographic base of the individual dunes. Many dunes are 40 to 50 feet high and a few are 80 feet high. The thickness of the sand also varies because of the irregular surface of the sand bars underlying the dunes. In many large areas the dune sand probably averages more than 20 feet thick. In the sand area on the uplands the dunes are usually less than 15 feet high and many are only 4 or 5 feet high.

Overburden.—Nearly all the sand dunes are covered with 1 to 2 feet of sandy soil which supports sufficient vegetation to fix the dunes in their present position. Locally, however, the wind has excavated blow-outs in the dunes so that the sand is exposed over a few acres.

Grain size.—The dunes are composed largely of medium-grained sand. Most of the dune sand appears to contain 20 to 50 per cent of grains coarser than 48-mesh, and 9 samples (36-40, 44-47, tables 1, 2) average 36 per cent. The sand is generally finer-grained in dunes in certain areas along the east margin of the terrace. The sand in an area southwest of Easton appears to be generally fine-grained, and one sample (42) contains only 3.5 per cent coarser than 48-mesh. A sample (43) from the dunes near Kilbourne contains only 5 per cent coarser than 48-mesh. The sand on the upland east of the terrace is generally still finer-grained. A sample (41) from near Mason City, contained only 2 per cent coarser than 48-mesh.

In general the finer-grained sands contain more material passing 270-mesh, the amount varying from 2 to 8 per cent. Although some of the coarser sands contain less than 1 per cent passing 270-mesh, some have as much as 5 per cent.

Composition.—The feldspar content of the samples of dune sands varies from 14 to 23 per cent. The finer-grained sands commonly contain more feldspar than the coarser. Nine samples of the coarser-grained sand contain an average of 16 per cent feldspar, and range from 14 to 18 per cent. The sample of fine-grained sand from Kilbourne contains 16 per cent feldspar. The Easton sand, which is still finer-grained, contains 19 per cent feldspar, and the finest-grained sand, from Mason City, contains 23 per cent feldspar.

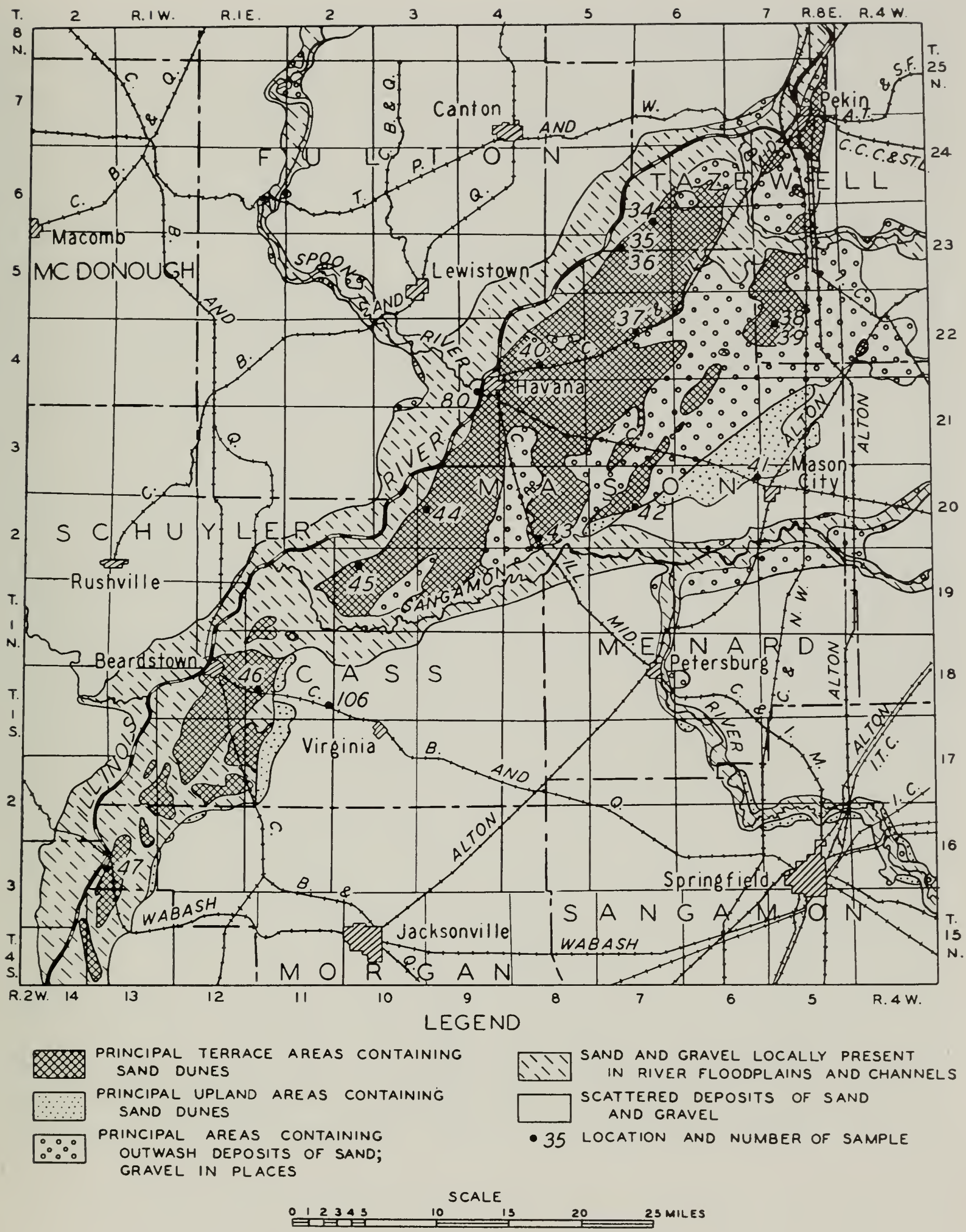

Fig. 7.—Sand and gravel deposits in the Havana area.

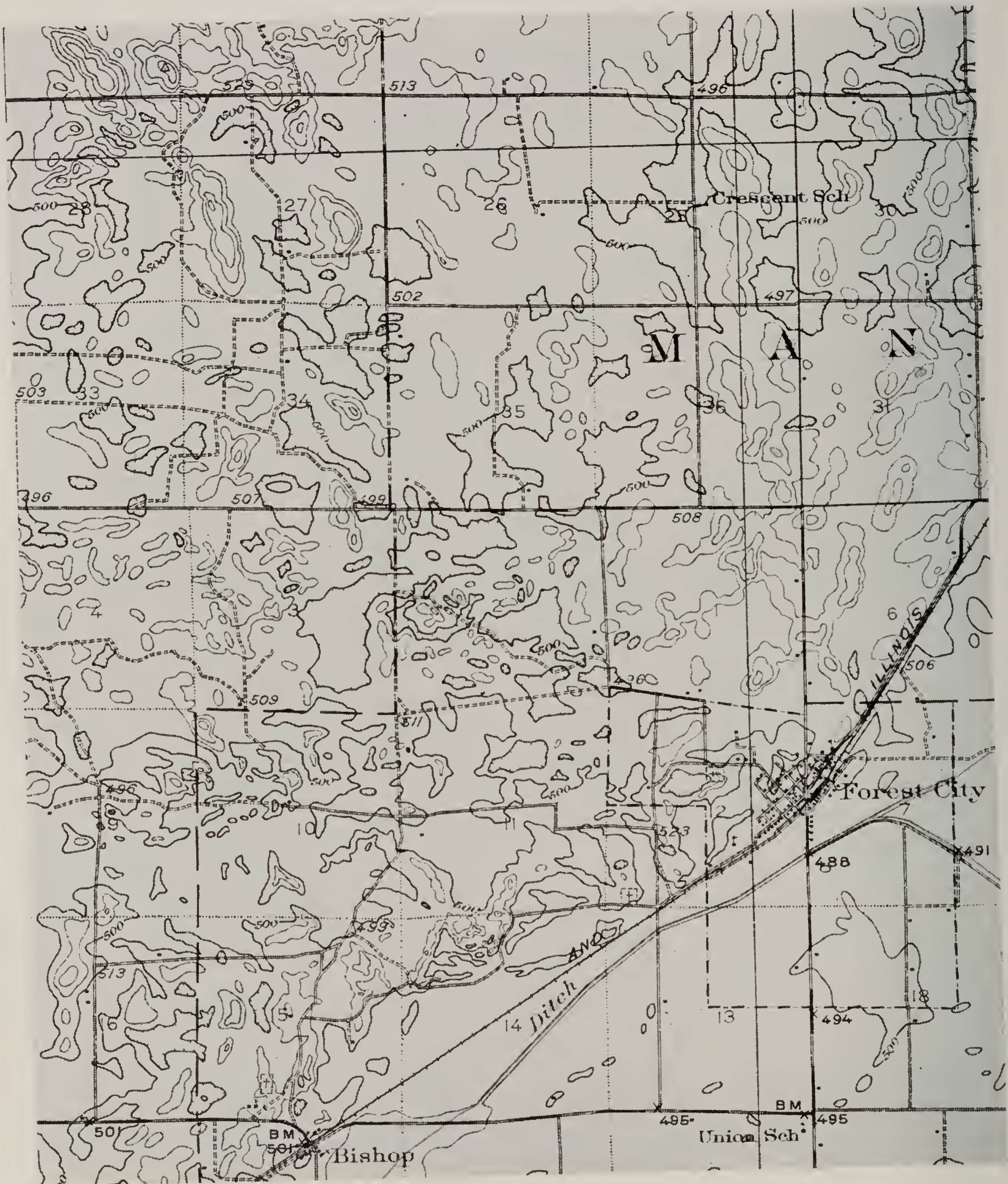

Fig. 8.—Topographic map of a typical area of sand dunes in the Havana map-area. The southwest corner of the area is nine miles northeast of Havana. (Part of Manito quadrangle—contour interval 20 feet—scale shown by the land-sections which are approximately one mile square.)

Most of the dune sand is noncalcareous but the thickness of the noncalcareous zone is variable. The noncalcareous sand is at least 10 to 15 feet thick at many places, and locally as much as 25 feet is exposed.

The only place observed where the calcareous dune sand was relatively thick was southwest of Green Valley (Delavan quadrangle), where a road-cut in the top of a dune in the SW. ¼ SE. ¼ SW. ¼ sec. 8, T. 22 N., R. 5 W., exposes 5 feet of noncalcareous sand (sample 39) over 3 feet of calcareous sand (sample 38). The lower 15 to 20 feet of this dune was not exposed but is probably all calcareous. There are not sufficient outcrops in other dunes in this vicinity to determine whether or not this is the general condition for this tract of dunes.

In the upland dunes the noncalcareous sand is at least 4 to 6 feet thick at many places. At one place calcareous sand is only 5 feet below the surface but at another the noncalcareous zone is at least 7 feet thick.

Size of deposits.—The Havana area contains many billions of tons of dune sand. Some of the individual dunes are very large. One dune about 80 feet high, northwest of Forest City (in sec. 21 at the northwest corner of figure 8) is estimated to contain approximately 10 million tons of sand. A few of the larger deposits near the railroads are listed below:

Baltimore and Ohio Railroad—southeast of Beardstown in secs. 19 and 30, T. 18 N., R. 11 W. (Arenzville quadrangle).

Alton railroad.—at Pekin in secs. 25, 26, 35, and 36, T. 25 N., R. 5 W., and secs. 2 and 11, T. 24 N., R. 5 W. (Peoria quadrangle); fine-grained sand occurs in scattered deposits northeast of Mason City in secs. 28, 32, and 33, T. 21 N., R. 5 W., and sec. 5, T. 20 N., R. 5 W.

Chicago and Illinois Midland Railroad—near Stoehrs in secs. 16, 17, 19, and 20, T. 24 N., R. 5 W. (Peoria quadrangle); between Parkland and Havana, especially southwest of Manito in sec. 29, T. 23 N., R. 6 W., northeast of Forest City in sec. 6, T. 22 N., R. 6 W., southwest of Bishop in secs. 21 and 22, T. 22 N., R. 7 W., (Manito quadrangle), and at Eckard in secs. 27, 28, 32-34, T. 22 N., R. 8 W. (Manito and Havana quadrangles); southeast of Havana in secs. 7, 18, and 19, T. 21 N., R. 8 W. (Havana quadrangle); and near Kilbourne in sec. 33, T. 20 N., R. 8 W. (Chandlerville and Petersburg quadrangles).

Chicago and Northwestern Railroad—northwest of Green Valley in sec. 27, T. 23 N., R. 5 W.; southwest of Green Valley in secs. 3, 10, and 15, T. 22 N., R. 5 W. (Delavan quadrangle); fine-grained sand occurs in scattered deposits northeast of Mason City, especially in secs. 16, 22, and 27, T. 21 N., R. 5 W.

Chicago, Burlington and Quincy Railroad—south of Beardstown in secs. 35, 36, T. 18 N., R. 12 W., and secs. 1 and 2, T. 17 N., R. 12 W. (Arenzville quadrangle).

Illinois Central Railroad—between Poplar City and Havana, especially in secs. 19 and 30, T. 21 N., R. 7 W., and secs. 7 and 22-24, T. 21 N., R. 8 W. (Manito, Havana, and Petersburg quadrangles); fine-grained sand occurs in scattered deposits between Mason City and Teheran.

Wabash Railroad—south of Meredosia in secs. 22, 27, and 34, T. 16 N., R. 13 W. (Meredosia quadrangle).

Extensive deposits also occur near Illinois Waterway, especially near Havana, Bath, and Meredosia.

Many large deposits in the Havana area are not close to railroads but are crossed by paved highways, especially State Highway No. 78 near Bath, State Highway No. 10 east of Havana, and State Highway No. 100 south of Beardstown. Many other deposits are crossed by gravel roads.

The largest deposits of relatively fine-grained dune sand occur in the ridge which extends southwest from Easton, especially in an area about four miles long and a mile wide, the north end of which is about a mile southwest of Illinois Central Railroad and State Highway 10 at Easton. It is accessible by gravel roads.

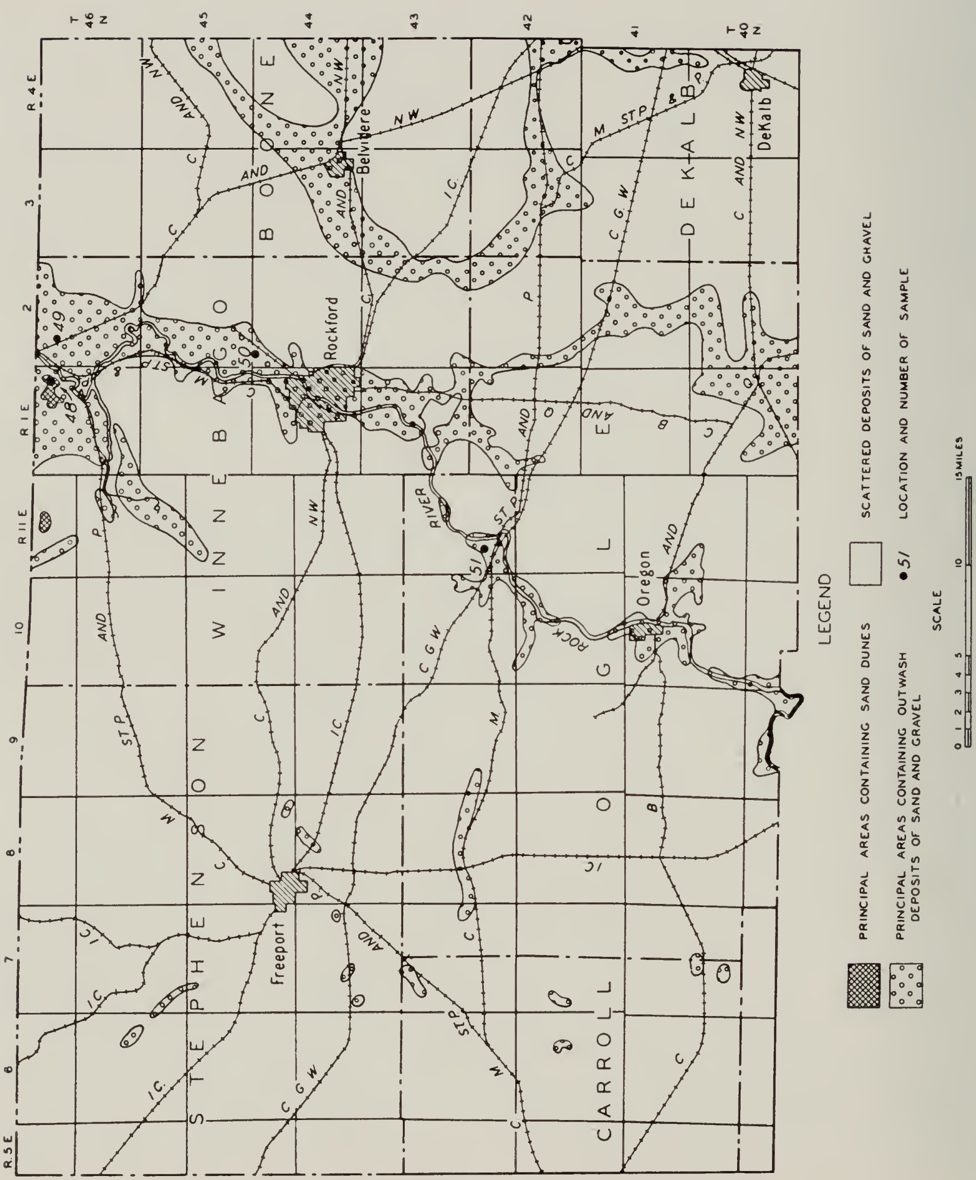

Fig. 9.—Sand and gravel deposits in the Rockford area.

OUTWASH DEPOSITS

Between the areas of sand dunes and along the west margin of the terrace near Illinois River, outwash deposits of sand and gravel occur below a thin overburden. The outwash deposits are well exposed in several pits north of Pekin and in pits along the edge of the terrace northwest of Manito.

Borings on the terrace generally penetrate 75 to 100 feet of sand and gravel overlying bedrock, and 25 to 50 feet of the deposits occurs above the level of Illinois River. As the terrace covers an area of about 500 square miles, there are probably many billions of tons of outwash sand and gravel in the area.

Where not overlain by sand dunes the outwash deposits have an overburden of 1 to 3 feet of soil and silt, except in some of the low more or less swampy areas along stream courses where a thicker overburden of silt and locally peat occurs.

Near the north end of the terrace area the outwash deposits consist principally of sandy gravel with beds of pebbly sand. Further south the materials are principally sand, but they usually contain scattered pebbles and locally gravelly lenses. The gravel deposits are well exposed in pits north of Pekin in sec. 23, T. 25 N., R. 5 W., and good exposures of the sand and pebbly sand deposits occur in pits northwest of Manito in the SE. ¼ SW. ¼ sec. 2 and SW. ¼ SW. ¼ sec. 16, T. 23 N., R. 7 W. (Manito quadrangle).

The outwash deposits are generally all calcareous where overlain by dune sand, but elsewhere the upper part, locally as much as 15 feet thick, is noncalcareous. The outwash deposits generally contain less feldspar than the dune sands but after the carbonates are removed they have about the same feldspar content. They are lighter in color and have less iron oxide stain on the grains than the dune sands. A sample (34) representing 20 feet of calcareous pebbly sand exposed in a pit along the edge of the terrace about five miles northwest of Manito contains 10 per cent feldspar but the 8- to 270-mesh fraction, when free of 20 per cent acid-soluble material, contains 15 per cent feldspar. A sample (35) from 25 feet of calcareous outwash sand exposed in a pit about three miles southeast of the above pit is similar in grain size to the dune sands and contains 14 per cent feldspar but when free of 9 per cent acid-soluble material it contains 16 per cent feldspar.

Rockford Area

In the Rockford area (fig. 9) large outwash deposits of sand and gravel occur in terraces along Rock and Pecatonica rivers and locally in the upland areas. Sand dunes occur locally near Rockton.

DUNE SAND

Sand dunes are present in a few areas on a large terrace west of Rockton and on the upland farther west. The dunes are mostly broad with gentle slopes, rarely more than 5 to 10 feet high, and are scattered. The distribution of the dune sand is shown on the Soil Survey map of Winnebago County.

The dune sand is mostly noncalcareous but overlies calcareous outwash sand. A sample (48, tables 1, 2) representing 5 feet of dune sand exposed in a small pit 1½ miles west of Rockton contains 50 per cent coarser than 48-mesh. It contains only 8 per cent of feldspar, considerably less than in most Illinois dune sands.

Although the area as a whole contains a large quantity of dune sand, the scattered distribution of the dunes and their relatively low height makes them less favorable than dunes in the other areas.

OUTWASH

Large deposits of gravel, commonly containing beds of pebbly sand, occur in terraces along Rock River. The distribution of the terraces is shown on the topographic maps of the Rockford, Pecatonica, Kings,[19] Oregon, and Dixon[20] quadrangles. Because of variations in

[19] Bretz, J Harlen, Geology and mineral resources of the Kings quadrangle: Illinois Geol. Survey Bull. 43C (Extract from Bull. 43), 1923.

[20] Knappen, R. S., Geology and mineral resources of the Dixon quadrangle: Illinois Geol. Survey Bull. 49, 1926.

Fig. 10.—Sand and gravel deposits in the Prophetstown area.

the surface of the underlying bedrock the thickness of the deposits is highly variable but in some areas they are as much as 100 feet thick and locally as much as 250 feet thick. Except for a thin weathered zone along the top they are all calcareous. Samples collected from pits at South Beloit (49), Rockford (50), and Byron (51), contained 12, 7, and 10 per cent feldspar, but the 8- to 270-mesh fractions, when free of 17, 19, and 19 per cent acid-soluble material, contain 15, 15, and 12 per cent feldspar, respectively.

Prophetstown Area

Many square miles in the Prophetstown area (fig. 10) are covered by sand dunes. The sand dunes overlie outwash deposits of sand and gravel in terraces along Rock River valley.

SAND DUNES

The sand dunes on the terraces occur both in ridge-like areas mostly elongated roughly northeast-southwest and in large irregular-shaped areas. Many of the individual dunes are ridges with their long direction usually northwest-southeast and with their northeast or lee slope much steeper than the southwest or windward slope (fig. 11). East of the terraces the sand dunes extend onto the uplands which are locally so near the level of the terraces that the exact position of the valley-wall is concealed by the dunes. On the terraces the dunes overlie sand and gravel but on the upland they overlie silt (loess) or pebbly silty clay (till).

The distribution of most of the dunes is well shown on the topographic maps of the Morrison, Prophetstown, Orion, Geneseo, Annawan, and Buda[21] quadrangles, and on the Soil Survey maps of Lee, Whiteside, Henry, and Bureau counties. Some of the largest areas of dunes occur near Amboy in Lee County, near Tampico, Prophetstown, and Erie in Whiteside County, near Hooppole, Annawan, and Geneseo in Henry County, and near Normandy, New Bedford, and Dingley in Bureau County.

[21] Ekblaw, George E., Preliminary report on the sand and gravel resources of the Buda quadrangle: Illinois Geol. Survey Inf. Cir. 3, 1932.

Thickness and overburden. — Many sand dunes in the area are 50 to 75 feet high, and there are hundreds of dunes 15 to 25 feet high. In parts of the area the dunes are scattered but in many large tracts the dune sand will average 20 feet or thicker. The dune sand commonly has an overburden of 1 to 2 feet of soil and silty sand, except in the small areas of blow-outs where the sand is exposed.

Grain size.—The dune sand is similar in grain size to that in the other areas. Ten samples (52-61, tables 1, 2) average 28 per cent coarser than 48-mesh, ranging from 8 to 53 per cent. Most of the samples contain 1 to 3 per cent of material finer than 270-mesh. The sand in the upper few feet of most dunes is higher in silt and clay than the lower part of the deposit. One sample (60) representing the upper 2 feet of sand contains 12.2 per cent finer than 270-mesh.

Composition.—The amount of feldspar in the 10 samples studied varied from 9 to 23 per cent. The per cent of feldspar is higher in the west part of the area than in the east. Four samples (52-55) from deposits in Lee County average 10 per cent feldspar and are thus similar to the one sample of dune sand from farther up the valley near Rockton (Rockford area) which contains 8 per cent feldspar. Two samples (56, 57) from a dune near Normandy in Bureau County average 14 per cent feldspar, and four samples (58-61) farther west in Whiteside and Henry counties average 19 per cent feldspar. In two dunes, where both the calcareous and noncalcareous sand were sampled (56-59), the noncalcareous sand contains a little more feldspar than the calcareous sand.

The lower part of the sand in some of the dunes is calcareous, two samples (56, 58) containing 7 and 10 per cent acid-soluble material. The thickness of the noncalcareous sand is variable but it was 6 feet or more in all the exposures examined and is at least as much as 11 feet in some places. From the scattered outcrops examined it appears that more of the dunes in the area contain calcareous sand than in the other areas.

Fig. 11.—Topographic map of a typical area of sand dunes in the Prophetstown map-area. (Part of the Prophetstown quadrangle—contour interval 10 feet—scale shown by the land-sections which are approximately one mile square.)

Size of deposits.—The sand dunes in the Prophetstown area contain several billion tons of sand. Some of the larger deposits located along the railroads are as follows:

Chicago and Northwestern Railroad—near Normandy, especially in secs. 2, 11, and 14, T. 18 N., R. 7 E.; near Hahnemann, in sec. 24, T. 19 N., R. 7 E., and secs. 7, 18, and 19, T. 19 N., R. 8 E.; near Nelson, in secs. 15, 29, 31, and 32, T. 21 N., R. 8 E.

Chicago, Burlington and Quincy Railroad—at Prophetstown, in secs. 4, 5, 8, and 9, T. 19 N., R. 5 E. (Prophetstown quadrangle) (the dunes in that part of sec. 4 south of the railroad (fig. 11) probably contain more than 6 million tons of sand, a large part of which may be calcareous); near Tampico, in secs. 14 and 24, T. 19 N., R. 6 E. (Prophetstown quadrangle) and secs. 19 and 20, T. 19 N., R. 7 E.; near Erie, in secs. 6-8, T. 19 N., R. 4 E., and secs. 14 and 15, T. 19 N., R. 3 E.

Chicago, Rock Island and Pacific Railroad—west of Geneseo, especially in secs. 12 and 13, T. 17 N., R. 2 E. (Geneseo quadrangle).

Hooppole, Yorktown and Tampico Railroad (narrow gauge)—south of Tampico, especially in sec. 34, T. 19 N., R. 6 E.

Many large areas of sand dunes not near the railroads are crossed by paved roads, especially State Highway No. 78 northwest of Hooppole and between Hooppole and Annawan, State Highway No. 88 south of Sterling, State Highway No. 82 north of Atkinson and north of Geneseo, State Highway No. 26 south of Dixon, and State Highway No. 92 at many places from Rock River east to Walnut.

OUTWASH

The outwash deposits which underlie the dunes and are locally exposed in the inter-dune areas and along the margin of the terrace near Rock River consist largely of calcareous pebbly sand and locally contain lenses of gravel. The deposits are variable in thickness but many borings on the terrace penetrate 50 to 75 feet of sand and gravel. The deposits are similar in composition to the outwash deposits along Illinois Valley. The 8- to 270-mesh fraction of a sample (62) of pebbly sand from near Prophetstown contains 13 per cent feldspar.

Large deposits of outwash sand occur in elongate hills in the high terrace area north of Rock Valley and south and east of Morrison. The sand is mostly fine-grained, calcareous, and is locally interbedded with silt. A sample (63) from one of these hills at Round Grove contains 8 per cent acid-soluble material and 39 per cent finer than 270-mesh. The sample as a whole contains 13 per cent feldspar but the fraction coarser than 270-mesh contains 21 per cent feldspar.

Savanna Area

In the Savanna area (fig. 12) sand dunes occur on terraces of outwash sand and gravel in Mississippi Valley. Large quantities of sand and gravel also occur along the channel of Mississippi River, as described elsewhere (p. 50).

DUNE SAND

Sand dunes occur at many places on a large terrace which, except for a few short breaks, is continuous from near Blanding in Jo Daviess County south to the edge of the area. Some of the principal sand dune areas are north of Savanna and near Thomson in Carroll County, near Fulton and East Clinton in Whiteside County, and near Cordova in Rock Island County. The distribution of the dunes in Whiteside and Rock Island counties is shown on the Soil Survey maps of these counties.

Dune sand more or less mixed with sandy silt (loess) occurs on the Mississippi Valley bluffs and in a belt half a mile to one mile wide on the adjacent uplands. As the dune sand is commonly silty and has not been mapped separately from the sandy loess, it is not shown on figure 12. These deposits are a possible source of finer-grained sand than that on the terraces.

Thickness and overburden.—In the higher dunes on the terraces the sand is 40 to 50 feet thick. Many dunes are 15 to 20 feet high and in some areas they are closely grouped so that the sand will average 10 to 15 feet thick. Large areas of the terraces have a thinner mantle of dune sand. The sand has a soil cover 6 inches to 2 feet thick except in the numerous blow-outs.

Grain size.—Most of the dune sand on the terraces appears to be a little coarser-grained than that in the areas previously described and about the same grain size as the dune sand in the Oquawka area. Five samples (64, 66-68, 79, tables 1, 2) average 46 per cent coarser than 48-mesh and range from 22 to 62 per cent. In four samples the amount of material finer than 270-mesh varies from 0.7 to 1.6 per cent and the other sample, which represents only the upper 5 feet of sand, contains 4.5 per cent finer than 270-mesh.

Composition.—The five samples of dune sand contain an average of 20 per cent feldspar, ranging from 17 to 22 per cent, which is slightly higher than in other dune areas. These sands, although coarser-grained than the dune sands in other areas, have a feldspar content about equal to that of the finest-grained sands in the other areas. The dunes of finer-grained sand along the bluffs of Mississippi Valley may contain a still higher percentage of feldspar, but at most places the finer-grained sands have a higher content of silt and this may offset a higher feldspar content. Most of the samples studied contain about twice as much soda-lime feldspar as potash feldspar.

On the terraces all of the dune sand examined is noncalcareous but on the bluffs only the upper 5-10 feet of the fine-grained sand is noncalcareous.

Size of deposits.—As detailed topographic maps of the principal sand areas are not available, it is difficult to estimate the quantity of sand available. However, in several areas there are probably over 5 million tons of sand per square mile. Some of the largest deposits located along or near the railroads are as follows:

Chicago and Northwestern Railroad—east of East Clinton, in secs. 34 and 35, T. 22 N., R. 3 E., and sec. 3, T. 21 N., R. 3 E.

Chicago, Burlington and Quincy Railroad—east of East Clinton, in secs. 3, 4, 9, and 10, T. 21 N., R. 3 E.; between Fulton and Savanna, especially in secs. 1, 2, and 11, T. 22 N., R. 3 E.; north of Savanna, especially in secs. 17 and 18, T. 25 N., R. 3 E.; near Hanover Station in sec. 29, T. 26 N., R. 2 E.; near Blanding, in secs. 3, 11, 13, and 14, T. 26 N., R. 1 E. (Galena quadrangle).

Chicago, Milwaukee, St. Paul, and Pacific Railroad — north of Cordova, especially in secs. 4, 5, 8, 9, and 17, T. 20 N., R. 2 E. (extensive but thin deposits of dune sand on outwash sand); between Fulton and Savanna, especially in secs. 1, 2, and 11, T. 22 N., R. 3 E.

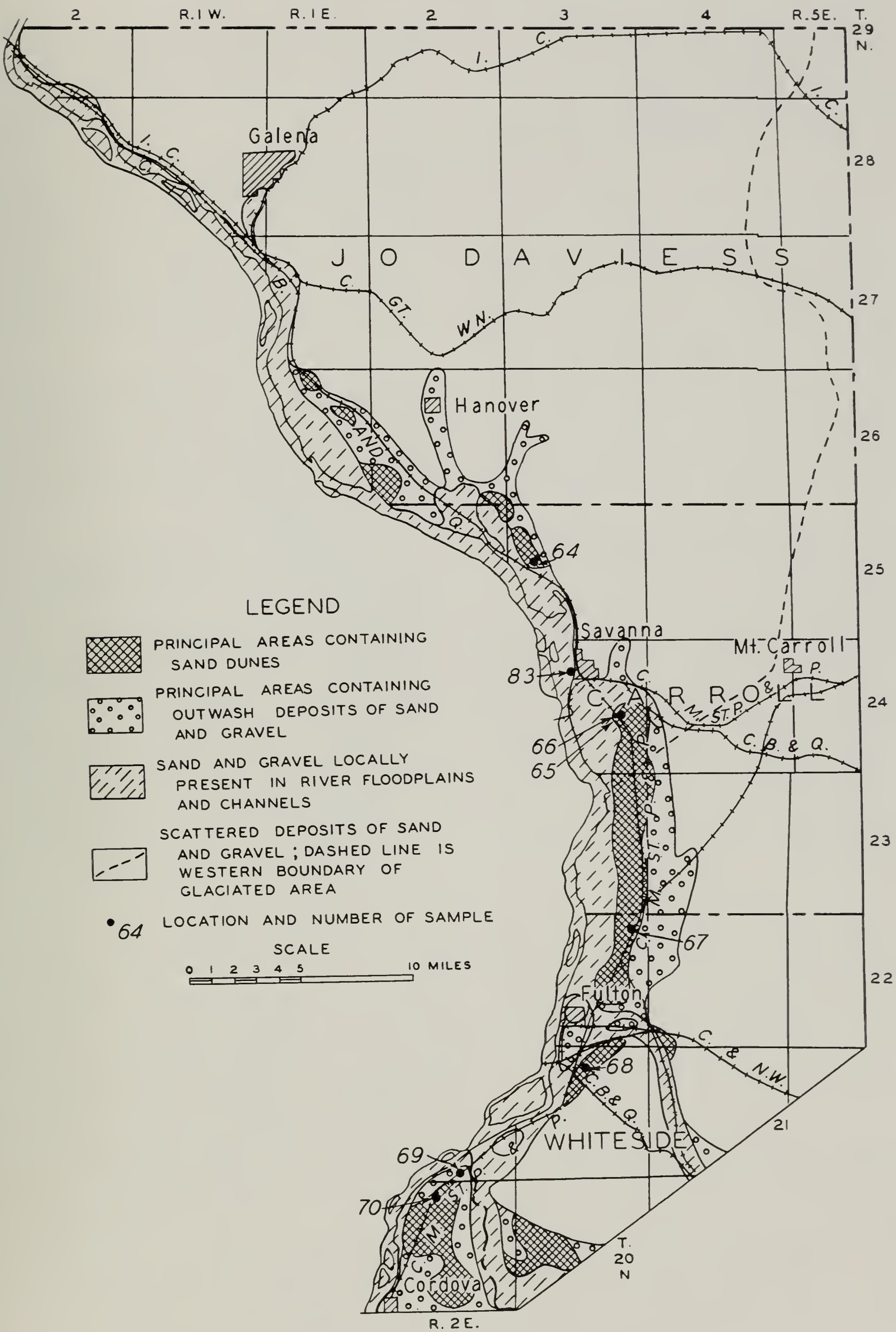

Fig. 12.—Sand and gravel deposits in the Savanna area.

Many of the deposits listed above are within a mile of Mississippi River.

Large deposits of dune sand farther from the railroads occur east of Cordova, in secs. 33 and 34, T. 20 N., R. 2 E., and secs. 19, 20, 29, and 30, T. 20 N., R. 3 E.

OUTWASH SAND AND GRAVEL

Large deposits of outwash sand and gravel underlie the terraces. Except where overlain by dune sand they have an overburden of 1 to 2 feet of soil. At the few places where well exposed, these deposits are noncalcareous and they thus differ from the outwash deposits in the areas previously described, which were calcareous except in a thin weathered zone at the top. As only the upper 25 feet was examined, the lower deposits may be calcareous in part. The terrace deposits are generally more than 100 feet thick and in places are as much as 200 feet thick. A sample (65) from a gravel pit about three miles southeast of Savanna contains 19 per cent feldspar but the 8- to 270-mesh fraction contains 21 per cent feldspar. Another sample (69) from a gravel pit about two miles southwest of Albany contains about 11 per cent feldspar but the 8- to 270-mesh fraction contains 22 per cent feldspar.

The outwash sand and gravel is available in large quantities at many places along all the railroads on the terraces.

Oquawka Area

The Oquawka area (fig. 13) contains large deposits of dune sand overlying glacial outwash deposits of sand and gravel in terraces along Mississippi River. Sand and gravel also occurs in the channel of Mississippi River, as described elsewhere (p. 50).

DUNE SAND

Many large areas of dune sand occur on a terrace which extends from six miles north of New Boston in Mercer County to Lomax in Henderson County. Some of the largest deposits of dune sand occur near New Boston and Keithsburg in Mercer County, and near Milroy, Oquawka, and Gladstone in Henderson County. The dunes are well shown on the topographic maps of the Keithsburg, Oquawka, Burlington, and Lomax quadrangles. Those in Mercer County are shown on the soil map of that county.

Dunes of sand mixed with hills of sandy loess occur on the upland near Mississippi Valley in extreme western Rock Island County especially in secs. 7, 8, 17, and 18, T. 16 N., R. 5 W. As the deposits appear to be predominately silt and their extent is uncertain they are not mapped in figure 13.

Thickness and overburden.—A few of the dunes on the terraces are 50 to 60 feet high and many are 20 to 30 feet high. The dune sand has a thin soil cover only 1 to 2 feet thick and locally the sand is exposed in blow-outs covering several acres.

Grain size.—The dunes are similar in grain size to those in the Savanna area. Four samples (72, 73, 75, 76, tables 1, 2) average 34 per cent coarser than 48-mesh and range from 15 to 54 per cent. They contain 1 to 2 per cent of material finer than 270-mesh.

Composition.—The four samples of dune sand average 21 per cent feldspar and range from 18 to 23 per cent, which is essentially the same as in the dunes in the Savanna area and a little higher than in the dunes in other areas.

The exposed dune sand is noncalcareous.

Size of deposits.—The area contains many millions of tons of dune sand. Large deposits occur along Chicago, Burlington, and Quincy Railroad almost continuously between Keithsburg and Oquawka, especially between Milroy and Keithsburg (Keithsburg and Oquawka quadrangles) and also north of Keithsburg, in sec. 3, T. 13 N., R. 5 W. (Keithsburg quadrangle); along Minneapolis and St. Louis Railroad east of Keithsburg, in sec. 19, T. 13 N., R. 4 W., and secs. 14, 22-24, T. 13 N., R. 5 W. (Keithsburg quadrangle). Many large deposits occur close to Mississippi River, especially at New Boston, Keithsburg, and Oquawka. Other large de-

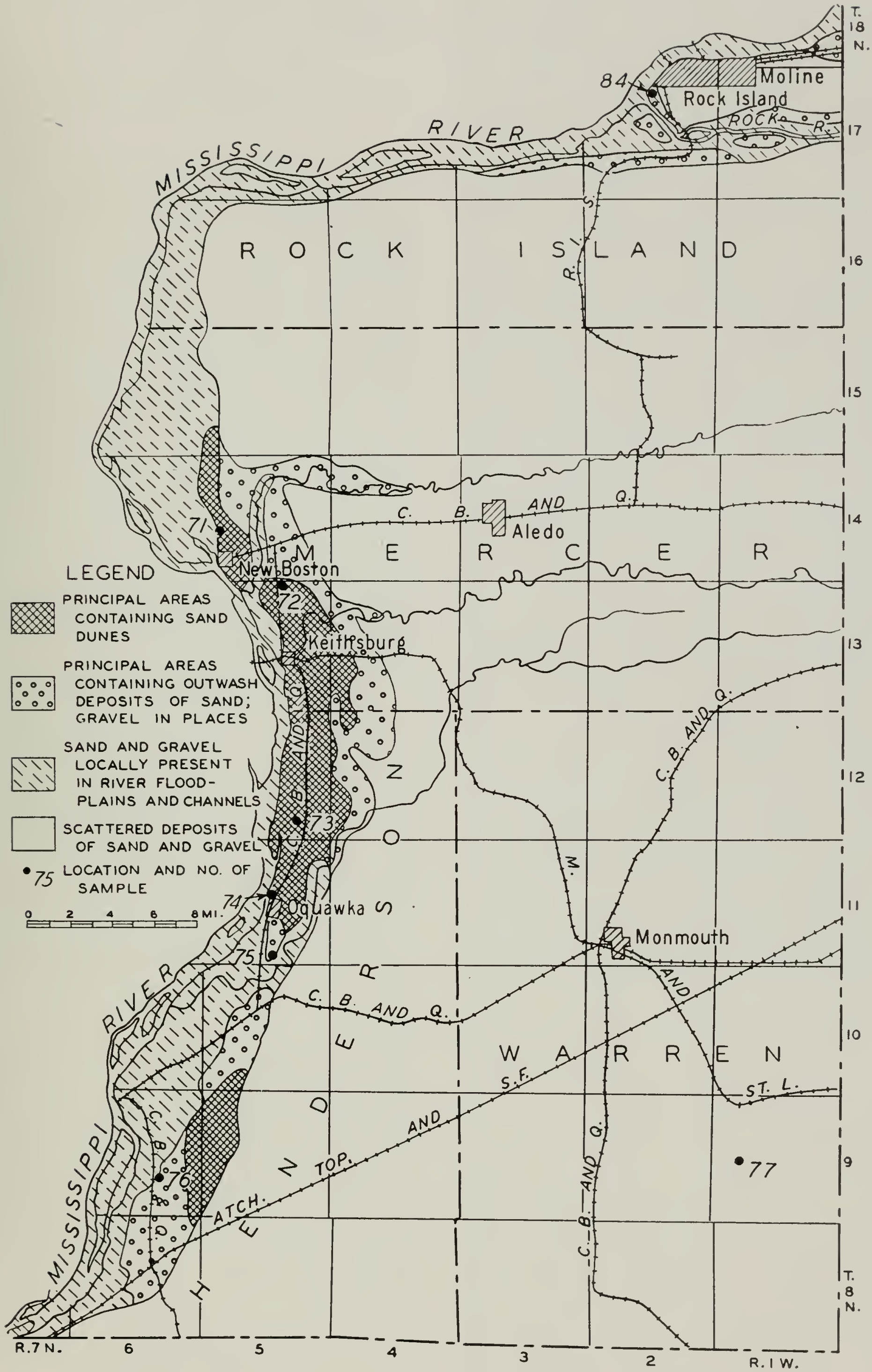

Fig. 13.—Sand and gravel deposits in the Oquawka area.

posits occur along the outer edge of the terrace for six miles north of New Boston and along the inner edge of the terrace about four miles south of Gladstone (Burlington and Lomax quadrangles).

OUTWASH SAND

The outwash deposits are well exposed at several places along the edge of the terrace near Mississippi River. The deposits are generally more than 100 feet thick and are more than 150 feet thick in some places. The upper 25 to 50 feet is above the level of Mississippi River. Except where overlain by dune sand the outwash deposits have only a thin overburden of soil 1 to 2 feet thick. Along the channels of Edwards and Pope rivers and other streams crossing the terrace, the outwash deposits are covered by mixed sand and silt alluvium. Where exposed the deposits are mostly medium-grained sand but locally they contain a few pebble streaks and more rarely lenses of gravel. The deposits are mostly light gray, nearly white, but in many places the upper 5 to 10 feet is stained light brown with iron oxide. Where overlain by dune sand the deposits, at least locally, are comparatively free from iron stain. All the outwash sand examined was noncalcareous. A sample (71) representing the upper 25 feet of sand exposed in a pit about two miles north of New Boston contains 23 per cent feldspar, and a sample (74) representing 10 feet of sand at Oquawka contains 22 per cent feldspar.

As the outwash deposits are similar in grain size to overlying dune sands and contain about the same amount of feldspar they might not have to be differentiated in working the deposits. The greater uniformity of grain size of the dune sand may make it preferable. However, the smaller amount of ironstain on the grains may favor the outwash sands.

Very large deposits of outwash sand are available along the railroads except where covered by thick dune sand.

A sample (77) of outwash sand from the upland area near Abingdon, an older deposit unrelated to the terrace deposits, is a noncalcareous medium-grained sand containing 8 per cent feldspar.

Mississippi, Illinois, Ohio, and Wabash Rivers

MISSISSIPPI RIVER

Enormous quantities of sand and gravel occur at many places along Mississippi River, the gravel principally along or near the deeper channels of the river and the sand in bars both in the river and along its shores. Many sand bars are exposed during intervals of low water and their location is shown on various river maps and the more recent topographic maps, especially those of the Keithsburg, Oquawka, Keokuk, Quincy, Barry, Nebo, Hardin, St. Charles, Granite City, Cahokia, Kimmswick, Crystal City, Renault, Chester, Altenburg, and Thebes quadrangles. To divert the currents into the major channels and maintain a sufficient depth of water for navigation, jetties have been built at many places along the river (many since the above maps were published). Behind these jetties immense quantities of sand have accumulated, and at favorable locations such deposits would probably be replaced almost as fast as removed. Sand and gravel have been dredged from the river bed at many places for use principally in the building industry.

Grain size.—Sand deposits of almost any grain size desired can be found along the river. The grain-size variations of Mississippi River deposits as shown by sieve analyses of 235 samples collected between Davenport, Iowa, and Cairo, Illinois, have been described.[22] Medium- and coarse-grained sand is available almost continuously along the river. The fine-grained sands appear to be more abundant south of East St. Louis. Very large bars, of which at least the upper few feet are fine-grained sands, occur along the river west of Valmeyer, near Chester, south of Thebes, and elsewhere along the river. The sands vary in content of material pass-

[22] Lugn, Alvin L., Sedimentation in the Mississippi River between Davenport, Iowa, and Cairo, Illinois: Augustana Lib. Pubs. No. 11, 1927.

ing 270-mesh, some of the very fine-grained sands being especially silty. However, many deposits contain little silt, and 9 of the 13 samples contain less than 1 per cent of material finer than 270-mesh.

Composition.—The Mississippi River sands contain more feldspar than sands in the other rivers and average higher than any other type of sand in Illinois (p. 20 and table 2). The 8- to 270-mesh fraction of 13 samples (83-95, tables 1, 2) of Mississippi River sand averaged 25 per cent feldspar, ranging from 16 to 34 per cent. The six samples (90-95) of sand from below East St. Louis contain more feldspar than the samples from up the valley, averaging 30 per cent and ranging from 26 to 34 per cent. Although this may be in part attributed to the finer-grain size of the sands south of East St. Louis, it appears to be a general characteristic inasmuch as a sample of coarse pebbly sand collected near Harrisonville, east of Valmeyer, is 89 per cent coarser than 48-mesh and contains 26 per cent feldspar (sample 93).

The Mississippi River sands are generally slightly calcareous. Two samples (85, 86) are noncalcareous but the remaining samples average about 2 per cent soluble in acid. Some of the acid-soluble material, perhaps as much as 1 per cent, is probably iron oxide and soluble minerals other than carbonates. The maximum amount soluble was 5 per cent (sample 92).

ILLINOIS RIVER

Bars of sand and gravel are common along the channel of Illinois River, especially south of Peoria. Partly because of dams there are no large sand flats exposed along Illinois River. Sand and gravel for commercial uses is dredged from the river, especially between Havana and Beardstown. Locally bars of sand occur on the floodplain near the river but these are usually silty and not large.

Three samples of sand collected from the edge of the river at Havana, (sample 80, tables 1, 2), Florence (sample 81), and Hardin (sample 82) are not as coarse-grained as much of the sand transported by the river. Omitting the material coarser than 8-mesh and finer than 270-mesh, which is variable, the sample from Havana contains 9 per cent feldspar, that at Florence 10 per cent, and that at Hardin 12 per cent, suggesting a slight increase in feldspar content down the valley.

OHIO RIVER

Large quantities of sand occur in bars along the channel of Ohio River. A sample (98, tables 1, 2) collected from a beach at the north end of Shawneetown is a noncalcareous sand containing 16 per cent feldspar. Samples from beaches at Rosiclare (99) and at Olmsted (100) are calcareous sands containing 11 and 6 per cent feldspar. The low feldspar content of these sands may be due to the introduction of Cretaceous-Tertiary sands which are exposed in the nearby bluffs and contain little feldspar. A sample (101) of calcareous fine-grained sand collected from the river's edge at Cairo contains 21 per cent feldspar.

WABASH RIVER

Wabash River transports large quantities of sand and gravel, and in its lower course many board sand flats are exposed along the river at low water. A sample (96, tables 1, 2) of pebbly calcareous sand from the shore of the river at Hutsonville contains 13 per cent feldspar, but the 8- to 270-mesh fraction contains 17 per cent feldspar. A sample of calcareous sand from a large bar near Grayville contains 19 per cent feldspar (sample 97).

Other Areas

In the parts of Illinois not included in the areas described above (fig. 2), sand and gravel deposits are locally present (fig. 1). Most of these deposits occur in the glaciated areas of the State and are outwash deposits similar to the outwash deposits in the areas described. Although some are large they are generally much less extensive than the deposits in the areas described and therefore are not individually described in this report.

Some of the largest sand deposits outside the map-areas occur near Greenville and Vandalia in Bond and Fayette counties. These are noncalcareous outwash deposits of pebbly sand mostly stained dark brown with limonite. A sample (78, tables 1, 2) from near Greenville contains 12 per cent feldspar.

Because of the relatively high feldspar content of the Mississippi River sands south of East St. Louis, dunes of comparable feldspar content might be expected to occur along the east bluffs of the valley and the adjacent upland areas. In this area, however, there are no large terraces along the bluffs as there are where sand dunes occur farther north, and the floodplain of the river occupies the entire bottomland of the valley. Because of the siltiness of the sands deposited on the floodplains, repeated flooding, and generally moist conditions of the floodplains, no extensive deposits of wind-blown sand have been formed. West of Anna wind-blown sand appears to fill a tributary ravine near the bluffs. The quantity of sand available is uncertain but there may be large quantities in scattered deposits of this character. A sample (79) from the deposit west of Anna is a noncalcareous fine-grained sand and contains 29 per cent feldspar.

TABLE 1.—DESCRIPTION OF SAMPLES

Sample No.	Location: Town near	Location: County	Location: Section ¼	Location: Section ¼	Location: Section ¼	Location: Section sec.	Location: Township	Location: Range	Material	Thickness sampled ft.	Thickness overburden ft.	Remarks
						Chicago Area (fig. 3)						
1	Chicago	Cook							Pebbly sand			Dredged from Lake Michigan off South Chicago; sampled from stock pile
2	Zion City	Lake	NE	NE	NW	23	46 N	12 E	Pebbly sand			Beach
3	Zion City	Lake	SE	SW	SW	14	46 N	12 E	Sand	5	½	Road-cut
4	Glencoe	Cook	SW	SW	SW	5	42 N	13 E	Sand			Beach
5	Calumet City	Cook	NW	SW	NW	18	36 N	15 E	Sand	5	½–1	Pit
6	Lansing	Cook	SE	SW	NE	31	36 N	15 E	Sand	6	½–1	Pit
7	Thornton	Cook	SE	NE	NW	35	36 N	14 E	Sand	3	4[a]	Below sample 8
8	Thornton	Cook	SE	NE	NW	35	36 N	14 E	Sand	4	0	Pit
9	Lansing	Cook	NW	NW	SW	36	36 N	14 E	Sand	5	½	Road-cut
10	Zion City	Lake	NW	SW	NW	27	46 N	12 E	Pebbly sand	6	1	Pit
11	Harvard	McHenry		SE	NE	2	45 N	5 E	Gravel	20	2	Sampled from stock pile at pit; +4-mesh screened out
12	Plainfield	Will	SW	NW	SE	15	36 N	9 E	Gravel	15	1	Pit
13	Rockdale	Will	SW	SW	NE	24	35 N	9 E	Pebbly sand	8	8	Pit
						Kankakee Area (fig. 4)						
14	Watseka	Iroquois	NE	NE	NW	20	26 N	12 W	Sand	3	8½[a]	Below sample 15
15	Watseka	Iroquois	NE	NE	NW	20	26 N	12 W	Sand	7	1½	Road-cut
16	Watseka	Iroquois	SE	SW	SE	18	26 N	12 W	Sand	2	1	Road-cut
17	Watseka	Iroquois	NW	NE	NE	8	27 N	12 W	Sand	8	½	Road-cut
18	Donovan	Iroquois	SE	NE	SE	19	28 N	11 W	Sand	3	3	Blow-out
19	Hopkins Pk.	Kankakee	SE	SE	SW	21	30 N	11 W	Sand	12	1	Road-cut
20	Hopkins Pk.	Kankakee	SW	SW	SE	16	30 N	11 W	Sand	3	1	Railroad-cut
21	Momence	Kankakee	SE	SE	SW	30	31 N	14 E	Sand	4	2	Road-cut
22	Kankakee	Kankakee	NE	SE	SW	33	31 N	11 E	Sand	15	½	Pit
23	Wilmington	Will	NE	SW	SW	22	32 N	10 E	Sand	12	1	Road-cut
24	Coal City	Grundy	SW	SE	NW	22	33 N	8 E	Sand	30	1	Overburden strip-coal mine
25	Coal City	Grundy	SE	SE	NW	22	33 N	8 E	Sand	10	6	Overburden strip-coal mine
26	Channahon	Will	NE	NE	NW	16	34 N	9 E	Gravel	20	2	Pit
27	Seneca	LaSalle	NW	NW	NW	36	33 N	5 E	Pebbly sand	11	0–10	Pit

TABLE 1.—DESCRIPTION OF SAMPLES—Continued

Sample No.	Location								Material	Thickness sampled ft.	Thickness overburden ft.	Remarks
	Town near	County	Section				Township	Range				
			¼	¼	¼	sec.						
						Lacon Area (fig. 6)						
28	Spring Valley	Bureau	SW	SE	NW	25	16 N	11 E	Sand	8	8–10	Pit
29	Hennepin	Putnam	SW	SW	SE	35	32 N	2 W	Sand	7	1	Road-cut
30	Henry	Putnam	NE	NW	SE	32	14 N	9 E	Gravel	5	8	Pit
31	Henry	Putnam	SW	SW	SW	26	31 N	2 W	Gravel	30	5–10	Pit
32	Chillicothe	Peoria	NE	NW	SW	17	11 N	9 E	Sand			Sand washed from gravel and returned to pit
33	Chillicothe	Peoria	SE	SE	NE	1	10 N	8 E	Sand	3	1½	Road-cut
						Havana Area (fig. 7)						
34	Manito	Tazewell	SW	SE	SW	2	23 N	7 W	Pebbly sand	20	10	Pit
35	Manito	Tazewell	SE	SW	SW	16	23 N	7 W	Sand	25	25	Overburden includes sample 36 and 14′ sand similar t sample 36
36	Manito	Tazewell	SE	SW	SW	16	23 N	7 W	Sand	10	1	Pit
37	Bishop	Mason	NW	NW	NE	22	22 N	7 W	Sand	10	1	Railroad-cut
38	Green Valley	Tazewell	SW	SE	SW	8	22 N	5 W	Sand	3	6[a]	Below sample 39
39	Green Valley	Tazewell	SW	SE	SW	8	22 N	5 W	Sand	5	1	Road-cut
40	Havana	Mason	NE	NE	NE	33	22 N	8 W	Sand	15	1	Railroad-cut
41	Mason City	Mason	NE	SE	NE	12	20 N	6 W	Sand	6	2½	Road-cut and auger boring
42	Easton	Mason	SE	SE	NE	15	20 N	7 W	Sand	4	1½	Road-cut
43	Kilbourne	Mason	SW	NW	NE	33	20 N	8 W	Sand	6	1–2	Road-cut
44	Bath	Mason	SW	NE	SE	18	20 N	9 W	Sand	6	1	Road-cut
45	Bath	Mason	NW	NW	NW	9	19 N	10 W	Sand	4	1	Road-cut
46	Beardstown	Cass	SW	SW	SW	20	18 N	11 W	Sand	8	1	Road-cut
47	Meredosia	Morgan	NW	NE	NE	28	16 N	13 W	Sand	10	2	Auger boring
						Rockford Area (fig. 9)						
48	Rockton	Winnebago	SW	NW	NW	12	46 N	1 E	Sand	5	1	Pit
49	S. Beloit	Winnebago	SE	SE	SE	8	46 N	2 E	Gravel	40	2	Pit
50	Rockford	Winnebago	NE	NW	NW	5	44 N	2 E	Gravel	30	2	Pit
51	Byron	Ogle	NW	SE	NE	29	25 N	11 E	Pebbly sand			Sand washed from gravel and returned to pit

Prophetstown Area (fig. 10)												
52	Amboy	Lee	NW	NW	SE	16	20 N	11 E	Sand	4	1	Road-cut
53	Amboy	Lee	NW	SW	SW	3	19 N	9 E	Sand	7	5[a]	Below sample 54
54	Amboy	Lee	NW	SW	SW	3	19 N	9 E	Sand	4	1	Road-cut
55	Nelson	Lee	SW	SW	SE	20	21 N	8 E	Sand	6	1	Road-cut
56	Normandy	Bureau	SW	SW	NW	11	18 N	7 E	Sand	10	7[a]	Below sample 57
57	Normandy	Bureau	SW	SW	NW	11	18 N	7 E	Sand	6	1	Road-cut
58	Annawan	Henry	NW	NE	NW	27	17 N	5 E	Sand	4	8[a]	Below sample 59
59	Annawan	Henry	NW	NE	NW	27	17 N	5 E	Sand	7	1	Road-cut
60	Atkinson	Henry	NW	NW	NE	10	17 N	4 E	Sand	2	½	Road-cut
61	Prophetstown	Whiteside	SW	NW	SW	9	19 N	5 E	Sand	4	2	Road-cut
62	Prophetstown	Whiteside	SE	NE	SW	19	20 N	5 E	Gravel	5	2	Pit
63	Round Grove	Whiteside	SE	NE	NW	25	21 N	5 E	Sand	8	6½	Road-cut
Savanna Area (fig. 12)												
64	Savanna	Carroll	NW	NE	SW	17	25 N	3 E	Sand	5	1	Road-cut
65	Savanna	Carroll	SW	SE	NE	23	24 N	3 E	Pebbly sand	6	12	Pit
66	Savanna	Carroll	SW	SE	NE	23	24 N	3 E	Sand	5	7	Pit
67	Fulton	Whiteside	SW	SW	NW	1	22 N	3 E	Sand	10	1	Blow-out
68	Fulton	Whiteside	SE	SW	SW	3	21 N	3 E	Sand	10	½	Blow-out
69	Albany	Rock Island	SE	NE	SW	34	21 N	2 E	Gravel	10	1½	Pit
70	Albany	Rock Island		NW	SW	4	20 N	2 E	Sand	3	½	Blow-out
Oquawka Area (fig. 13)												
71	New Boston	Mercer	SE	NW	NW	19	14 N	5 W	Pebbly sand	25	5	Pit
72	Keithsburg	Mercer	NW	NW	NE	3	13 N	5 W	Sand	7	1	Road-cut
73	Oquawka	Henderson	NE	NE	SW	35	12 N	5 W	Sand	3	3	Road-cut
74	Oquawka	Henderson	NE	NE	SW	15	11 N	5 W	Sand	10	5	Outcrop in river bank
75	Oquawka	Henderson	SE	NE	SW	34	11 N	5 W	Sand	5	2	Road-cut
76	Lomax	Henderson	NW	NW	NW	26	9 N	6 W	Sand	4	2–3	Road-cut
77	Abingdon	Warren		NE	NW	20	9 N	1 W	Sand	12	10	Outcrop along stream
Other Areas (fig. 2)												
78	Greenville	Bond	NE	SE	NW	10	5 N	3 W	Pebbly sand	10	3	Pit
79	Jonesboro	Union	SE	SW	SW	20	12 S	2 W	Sand	8	1	Pit
Illinois River (fig. 2)												
80	Havana	Fulton	SW	NE	SE	29	4 N	4 E	Pebbly sand			Bar on floodplain
81	Florence	Pike	NE	NE	NE	15	5 S	2 W	Pebbly sand			Beach
82	Hardin	Greene	SW	SE	SW	1	8 N	14 W	Gravel			Bar on floodplain

TABLE 1.—DESCRIPTION OF SAMPLES—Concluded

Sample No.	Location								Material	Thickness sampled ft.	Thickness overburden ft.	Remarks
	Town near	County	Section				Township	Range				
			¼	¼	¼	sec.						
						Mississippi River (fig. 2)						
83	Savanna	Carroll	SW	NE	NE	9	24 N	3 E	Pebbly sand			Beach
84	Rock Island	Rock Island	SW	NW	SW	3	17 N	2 W	Pebbly sand			Beach
85	Hamilton	Hancock		NE	SW	30	5 N	8 W	Pebbly sand			Beach
86	Louisiana	Pike	SW	SE	NW	13	7 S	6 W	Sand			Beach
87	Alton	Madison		SE	NE	14	5 N	10 W	Sand			Beach
88	Alton	Madison		SE	NE	14	5 N	10 W	Sand			Beach
89	Alton	Madison			NE	14	5 N	10 W	Pebbly sand			Dredged from river
90	East Carondelet	St. Clair					1 N	10 W	Sand			Beach at Davis St. ferry
91	Harrisonville	Monroe	NW	SW	NW	18	3 S	11 W	Sand			Bar in river
92	Harrisonville	Monroe	SE	SW	SW	18	3 S	11 W	Sand			Beach
93	Harrisonville	Monroe		SW	SW	18	3 S	11 W	Pebbly sand			Dredged from river
94	Chester	Randolph		NE	NW	23	7 S	7 W	Sand			Beach
95	Thebes	Alexander	NE	SW	SE	28	15 S	3 W	Sand			Beach
						Wabash River (fig. 2)						
96	Hutsonville	Crawford		NE	SE	29	8 N	11 W	Pebbly sand			Beach
97	Grayville	Wabash	SW	NE	NE	21	3 S	14 W	Sand			Beach
						Ohio River (fig. 2)						
98	Shawneetown	Gallatin	SE	SW	SE	29	9 S	10 E	Sand			Beach
99	Rosiclare	Hardin	SE	SW	SW	5	13 S	8 E	Sand			Bar on floodplain
100	Olmsted	Pulaski	NW	NW	SW	18	15 S	2 E	Pebbly sand			Beach
101	Cairo	Alexander		SE	SE	25	17 S	17 E	Sand			Beach
							Glacial Till					
102	Joliet	Cook	NW	NE	NE	31	36 N	12 E	Till	10	3–4	Road-cut
103	Wedron	LaSalle	NW	NE	SW	9	34 N	4 E	Till	10	3	Pit
104	Wedron	LaSalle	NW	NE	SW	9	34 N	4 E	Till	12	25	Pit
105	Greenville	Bond	NE	SE	NW	10	5 N	3 W	Till	10	13	Pit
106	Virginia	Cass	SE	SE	NW	36	18 N	11 W	Till	10	15+	Outcrop along stream

a. The overburden consists of sand represented by sample indicated under "remarks", and it would not be so large if the overlying sand were also used.

Table 2.—Sieve and Mineral Analyses—Explanation

*Condition**

A.—Sieve analysis of the part of the sample finer than 8-mesh in its natural condition. Percentage finer than 270-mesh determined by washing on 270-mesh sieve.

B.—Sieve analysis of the sample tested under A (excluding the —270-mesh fraction) after removing the carbonates and iron oxides by digesting in acid (HCl). Determined only for the calcareous samples.

C.—The percentage of each sieve-size soluble in acid is determined from the loss of weight of the material retained on each sieve-size after the acid treatment and resieving. In a few samples some aggregates in the coarser sieve-sizes break down during the acid treatment causing the finer fractions to show an increase after the acid treatment. Gains are marked +. Determined only for the calcareous samples.

D.—The mineral analyses of the calcareous samples were made of the sieve-fractions after the acid treatment and sieving (condition B), thus removing the carbonates and iron oxides. Of the noncalcareous sands only the individual sieve-sizes studied were acid treated, removing the iron oxides. Probably small amounts of other minerals were also dissolved from both types of samples.

E.—The mineral analysis of the —8 +270-mesh fraction of the samples, after acid treatment, is calculated from the mineral analyses of the individual sieve-fractions recorded under D combined with estimates of the composition of the remaining sieve-sizes represented in the sample. These estimates were based on the probable gradation between the sieve-sizes analyzed and on the analyses of other samples which show the general trend of the variations in mineral composition. Each sieve-size was weighted according to its amount as recorded under condition B. Reported only for the calcareous samples.

F.—The mineral analysis of the —8 +270 fraction of the calcareous samples in their natural condition is calculated from E by adding to the "others" the total amount acid-soluble—the carbonates and iron oxides—given under C, and proportionately reducing the amount of each mineral shown under E. As the noncalcareous samples contain only a small amount of acid-soluble material (rarely more than 2 per cent) this amount would not materially change the analyses and therefore the amount acid-soluble was generally not determined. The analysis is calculated directly from the analyses recorded under D with estimates of the composition of the intervening sieve-sizes as described under condition E.

G.—The total feldspar, acid-treated, is the sum of the potash and soda-lime feldspars in the mineral analysis above, under condition D. The total feldspar, natural, is the percentage of feldspar when the acid soluble minerals are included. It is calculated from the total feldspar, acid-treated, by taking into account the percentage of the acid-soluble material for each sieve-size given under condition C.

H.—The total feldspar in the sample, as sampled, is determined by reducing the total feldspar in the —8 +270-mesh fraction given under condition F by the amount which the inclusion of the +8-mesh and the —270-mesh fractions requires. It assumes that there is no feldspar in the +8-mesh and —270-mesh fractions. A small percentage of feldspar is no doubt present in these fractions but it is smaller than in the remainder of the sample and may not be recoverable commercially.

* A detailed description of the procedure followed in making these tests is given on pages 9-11.

TABLE 2.—SIEVE AND MINERAL ANALYSES

Sample No.[a]	1			2			3		
Type of deposit	Lake			Beach			Beach		
Calcareous	Yes			Yes			Yes		
% retained on 8-mesh	21			11			None		
Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)									
Mesh / Condition:[b]	A Natural	B Acid treated	C % Acid soluble	A Natural	B Acid treated	C % Acid soluble	A Natural	B Acid treated	C % Acid soluble
10	13.6	13.1	15	15.6	12.5	35			
14	12.4	11.9	15	13.2	10.4	37			
20	7.1	6.8	16	3.9	3.1	36	Tr.	Tr.	
28	7.8	7.3	17	5.1	4.2	34	0.1	0.1	
35	9.2	9.3	11	9.8	9.9	18	0.7	0.8	
48	15.5	16.6	6	28.3	32.3	8	14.6	15.9	0
65	16.5	17.7	5	18.3	21.2	6	55.8	56.6	6
100	13.6	14.1	8	5.1	5.1	19	25.2	24.8	8
150	2.5	2.1	24	0.2	0.2	25	2.6	1.7	38
200	0.8	0.6	38	0.1	0.1		0.5	0.2	
270	0.1	0.1		0.1	0.1		0.1	0.1	
—270	0.6	0.2		0.4	0.7		0.5	0.1	
Total	99.7	99.8	11	100.1	99.8	19	100.1	100.3	7

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated							E Acid treated (est.)	F Natural (est.)	D Acid treated		E Acid treated (est.)	F Natural (est.)	D Acid treated			E Acid tr. (est.)	Nat. (est.)
Mesh:	14	20	35	48	65	100	150	—8+270	—8+270	48	65	—8+270	—8+270	48	65	100	—8+270	—8+270
Quartz	8	31	74	75	81	75	70	55	49	76	75	65	52	78	82	67	77	72
Potash feldspar	4	7	6	6	7	10	12	7	6	3	5	5	4	2	3	5	3	3
Soda-lime feldspar	22	22	10	9	8	11	11	14	12	11	11	12	10	10	9	8	9	8
Shale, etc.	21	14	3	5	2	2	3	9	8	4	5	6	5	6	3	2	3	3
Chert	39	19	4	4	1	1	+	13	12	1	0	5	4	1	+	0	+	+
Heavy minerals	0	0	0	+	+	+	3	+	+	1	1	1	1	+	+	6	2	2
Others	6	7	3	1	1	1	1	2	13	4	3	6	24	3	3	12	6	12
Condition G[b]																		
Total feldspar:																		
Acid treated	26	29	16	15	15	21	23	21		14	16	17		12	12	13	12	
Natural	22	24	14	14	14	19	17		18	13	15		14	12	11	12		11
Condition H[b]																		
Total feldspar as sampled	14									12				11				

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	4	5	6	7
Type of deposit	Beach	Dune	Dune	Dune
Calcareous	Yes	No	No	No
% retained on 8-mesh	None	None	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Condition:[b] / Mesh	4: A Natural	4: B Acid treated	4: C % Acid soluble	5: A Natural	6: A Natural	7: A Natural
10						
14					Tr.	Tr.
20	Tr.	Tr.			0.1	Tr.
28	0.4	0.4	25		0.1	0.4
35	2.4	2.1	25	Tr.	0.5	2.8
48	12.0	12.3	13	1.6	5.6	13.8
65	29.6	31.3	9	3.3	29.3	29.6
100	50.8	50.0	15	68.3	46.6	41.6
150	4.4	3.6	30	24.2	14.3	10.8
200	0.3	0.2		1.6	1.8	0.6
270	Tr.	Tr.		0.1	0.1	Tr.
—270	0.4	0.1		0.9	1.4	0.4
Total	100.3	100.0	14	100.0	99.8	100.0

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	4: D Acid treated		4: E Acid treated (est.)	4: F Natural (est.)	5: D Acid treated			5: F Natural (est.)	6: D Acid treated			6: F Natural (est.)	7: D Acid treated			7: F Natural (est.)
Mesh:	65	100	—8+270	—8+270	65	100	150	—8+270	65	100	150	—8+270	48	65	100	—8+270
Quartz	76	72	73	63	75	70	71	70	82	74	66	75	73	77	77	75
Potash feldspar	7	8	8	7	9	16	15	15	8	13	16	12	9	9	12	11
Soda-lime feldspar	10	12	11	9	9	13	12	13	6	10	14	9	10	8	8	9
Shale, etc.	4	4	4	3	4	1	+	1	2	1	0	1	6	5	+	3
Chert	1	+	1	1	2	+	0	+	1	1	0	1	1	+	+	+
Heavy minerals	+	2	1	1	0	+	1	+	+	+	3	1	+	+	1	1
Others	2	2	2	16	1	+	1	1	1	1	1	1	1	1	2	1
Condition G[b] Total feldspar																
Acid treated	17	20	19		18	29	27		14	23	30		19	17	20	
Natural	15	18		16				28				21				20
Condition H[b] Total feldspar as sampled	16				28				21				20			

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	8	9	10	11
Type of deposit	Dune	Dune	Outwash	Outwash
Calcareous	No	No	Yes	Yes
% retained on 8-mesh	None	None	17	52

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	8: A Natural	9: A Natural	10: A Natural	10: B Acid treated	10: C % Acid soluble	11: A Natural	11: B Acid treated	11: C % Acid soluble
10	0.2		3.4	1.8	60	18.4	11.4	69
14	0.2		5.4	3.1	57	17.8	13.3	63
20	0.2		6.4	4.6	47	13.4	12.2	55
28	0.8	Tr.	12.8	11.3	35	14.5	16.4	43
35	2.6	0.4	22.0	23.1	23	11.5	16.5	35
48	8.2	2.0	33.7	38.9	15	10.5	16.9	22
65	17.4	5.0	11.7	13.8	14	4.6	7.2	29
100	50.8	35.4	2.0	2.0	25	2.4	3.4	34
150	18.2	46.8	0.2	0.2		0.7	0.8	43
200	1.2	6.0	0.2	0.2		0.7	0.7	50
270	Tr.	0.4	0.1	0.1		0.3	0.2	
—270	0.2	3.6	2.0	1.0		5.0	0.5	
Total	100.0	99.6	99.9	100.1	25	99.8	99.5	47

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	8: D Acid treated	8: D Acid treated	8: F Natural (est.)	9: D Acid treated	9: D Acid treated	9: D Acid treated	9: F Natural (est.)	10: D Acid treated	10: D Acid treated	10: E Acid treated (est.)	10: F Natural (est.)	11: D Acid treated	11: E Acid treated (est.)	11: F Natural (est.)
Mesh:	100	150	—8+270	35	100	150	—8+270	28	48	—8+270	—8+270	28	—8+270	—8+270
Quartz	70	72	70	49	75	75	74	26	69	56	42	53		
Potash feldspar	12	14	12	6	14	12	13	3	6	6	4	4		
Soda-lime feldspar	12	10	11	12	7	9	8	19	17	17	13	19		
Shale, etc.	3	1	4	28	2	2	2	33	7	14	11	10		
Chert	1	+	1	3	+	+	+	15	1	5	4	11		
Heavy minerals	+	1	+	+	+	1	1	0	0	+	+	0		
Others	2	2	2	2	2	1	2	4	+	2	26	3		
Condition G[b] Total feldspar:														
Acid treated	24	24		18	21	21		22	23	23		23	22	
Natural			23				21	14	20		17	13		12
Condition H[b] Total feldspar as sampled	23			20				14				5		

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	12	13	14	15
Type of deposit	Outwash	Outwash	Dune	Dune
Calcareous	Yes	Yes	No	No
% retained on 8-mesh	70	2	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	12 A Natural	12 B Acid treated	12 C % Acid soluble	13 A Natural	13 B Acid treated	13 C % Acid soluble	14 A Natural	15 A Natural
10	5.3	3.5	77	1.8	1.3	72		
14	5.2	4.7	69	4.2	2.9	74	Tr.	
20	7.2	7.5	65	6.0	4.0	75	0.1	Tr.
28	19.7	20.3	65	9.6	5.8	77	0.1	Tr.
35	27.5	28.6	65	13.5	9.8	73	0.2	0.2
48	22.3	26.1	60	20.7	24.0	57	2.4	0.8
65	4.9	6.2	57	16.8	24.4	46	9.6	6.6
100	1.4	1.7	57	14.4	22.5	42	32.2	35.2
150	0.4	0.6	50	2.8	3.7	50	20.8	26.5
200	0.4	0.6	50	1.4	1.3	65	24.2	22.5
270	0.5	0.4	70	0.5	0.3	80	4.9	2.8
—270	5.0	0.4		8.2	0.3		5.9	5.4
Total	99.8	100.6	64	99.9	100.3	59	100.4	100.0

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	12 D Acid treated	12 E Acid treated (est.)	12 F Natural (est.)	13 D Acid treated	13 E Acid treated (est.)	13 F Natural (est.)	14 D Acid treated	14 D Acid treated	14 D Acid treated	14 F Natural (est.)	15 D Acid treated	15 D Acid treated	15 F Natural (est.)
Mesh:	35	—8+270	—8+270	48	—8+270	—8+270	100	150	200	—8+270	100	200	—8+270
Quartz	46			70			69	70	69	68	77	63	71
Potash feldspar	2			6			7	7	9	9	10	14	12
Soda-lime feldspar	14			8			19	16	13	16	10	17	13
Shale, etc.	26			13			2	+	0	1	1	1	1
Chert	6			3			0	0	0	+	0	0	+
Heavy minerals	+			0			1	3	5	3	1	4	2
Others	6			+			2	4	4	3	1	1	1
Condition G[b] Total feldspar													
Acid treated	16	18		14	16		26	23	22		20	31	
Natural	6		6			6				25			25
Condition H[b] Total feldspar as sampled	1			5			24				24		

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	16	17	18	19
Type of deposit	Dune	Dune	Dune	Dune
Calcareous	No	No	No	No
% retained on 8-mesh	None	None	None	None
Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)				
Condition:[b]	A Natural	A Natural	A Natural	A Natural
Mesh				
10				
14			Tr.	
20		Tr.	0.1	Tr.
28	Tr.	Tr.	0.6	0.2
35	0.2	0.2	3.2	1.0
48	2.4	2.0	17.6	8.0
65	10.4	8.6	22.5	18.6
100	32.6	39.8	34.7	43.2
150	19.8	25.6	13.1	16.6
200	18.6	19.2	7.1	9.6
270	4.2	1.8	0.8	1.2
—270	11.4	3.2	0.3	1.8
Total	99.6	100.4	100.0	100.2

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated		F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated					F Natural (est.)
Mesh:	65	100	—8+270	48	100	200	—8+270	48	65	100	—8+270	48	65	100	150	200	—8+270
Quartz	83	79	73	83	80	68	75	83	83	79	79	77	80	72	68	67	73
Potash feldspar	7	10	11	6	9	13	11	5	8	10	9	6	10	12	13	12	11
Soda-lime feldspar	7	9	11	6	9	11	10	7	7	9	9	12	7	12	14	12	11
Shale, etc.	2	1	1	3	2	0	1	3	1	1	1	4	2	2	1	+	2
Chert	0	0	+	2	+	0	+	1	+	0	+	+	+	0	0	0	+
Heavy minerals	0	1	3	0	+	5	2	0	+	+	1	0	+	1	4	7	2
Others	1	+	1	+	+	3	1	1	1	1	1	1	1	1	+	2	1
Condition G[b]																	
Total feldspar																	
Acid treated	14	19		12	18	24		12	15	19		18	17	24	27	24	
Natural			22				21				18						22
Condition H[b]																	
Total feldspar as sampled	20			20				18				22					

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	20	21	22	23
Type of deposit	Dune	Dune	Dune	Dune
Calcareous	No	No	No	No
% retained on 8-mesh	None	None	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	A Natural	A Natural	A Natural	A Natural
10				
14		Tr.		Tr.
20	Tr.	0.4	Tr.	0.2
28	0.2	3.2	0.1	0.6
35	0.4	12.3	0.6	7.2
48	4.2	33.0	9.3	33.8
65	21.8	27.4	33.6	30.3
100	52.4	18.0	38.6	19.2
150	14.4	2.0	10.0	4.2
200	5.8	0.7	5.2	2.0
270	0.2	0.2	0.5	1.5
—270	1.0	2.9	2.2	2.0
Total	100.4	100.1	100.1	101.0

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated			F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated				F Natural (est.)	D Acid treated		F Natural (est.)
Mesh:	48	100	200	—8+270	28	48	100	—8+270	48	65	100	150	—8+270	48	100	—8+270
Quartz	82	78	64	78	50	79	77	76	83	84	78	72	78	80	81	78
Potash feldspar	7	10	13	10	6	5	9	7	6	8	9	11	9	6	8	7
Soda-lime feldspar	7	9	15	9	9	7	9	8	8	6	12	14	10	8	9	9
Shale, etc.	3	1	0	1	22	7	3	7	2	1	+	+	1	4	1	3
Chert	1	0	0	+	12	1	+	1	1	+	+	+	+	1	0	1
Heavy minerals	0	1	6	1	0	0	1	+	0	0	+	2	1	0	1	1
Others	+	1	2	1	1	1	1	1	+	1	1	1	1	1	+	1
Condition G[b]																
Total feldspar																
Acid treated	14	19	28		15	12	18		14	14	21	25		14	17	
Natural				19				15					19			16
Condition H[b]																
Total feldspar																
as sampled	19				15				19					16		

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	24	25		26			27		
Type of deposit	Dune	Outwash		Outwash			Outwash		
Calcareous	No	Slight		Yes			Yes		
% retained on 8-mesh	None	Trace		67			3		
Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)									
Mesh / Condition:[b]	A Natural	A Natural	C % Acid soluble	A Natural	B Acid treated	C % Acid soluble	A Natural	B Acid treated	C % Acid soluble
10				8.3	7.6	80	1.4	0.7	64
14				9.4	9.4	78	2.4	1.6	50
20	Tr.	4.6		10.3	12.9	72	5.2	4.2	39
28	.6	4.3		20.8	23.3	75	19.5	17.8	31
35	4.2	10.0		22.1	21.5	75	30.1	29.8	25
48	19.6	26.9		14.4	15.6	76	25.1	27.3	18
65	33.6	29.5		3.5	4.5	72	9.0	10.4	14
100	32.2	17.8		1.6	2.0	71	5.2	6.0	13
150	5.8	3.2		0.5	0.7	70	0.6	0.7	17
200	2.2	0.9		0.5	0.7	70	0.2	0.3	
270	0.2	0.2		0.2	0.4		0.1	0.1	
—270	1.6	2.9		8.5	0.4		1.3	0.8	
Total	100.0	100.3	1	100.1	99.0	76	100.1	99.7	24

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated			F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated	E Acid treated (est.)	F Natural (est.)	D Acid treated		E Acid treated (est.)	F Natural (est.)
Mesh:	35	65	100	—8+270	48	100	—8+270	28	—8+270	—8+270	28	48	—8+270	—8+270
Quartz	70	77	77	76	75	77	74	24			50	80	67	50
Potash feldspar	4	9	10	9	7	8	7	1			4	6	6	5
Soda-lime feldspar	11	9	10	9	8	8	8	14			20	7	12	9
Shale, etc.	9	4	2	4	7	5	7	48			12	5	8	6
Chert	4	+	+	+	2	0	2	11			14	1	6	5
Heavy minerals	0	+	+	1	+	2	1	0			0	0	+	+
Others	2	1	1	1	1	+	1	2			+	1	1	25
Condition G[b] Total feldspar:														
Acid treated	15	18	20		15	16		15	18		24	13	18	
Natural				18			15	4		4	17	11		14
Condition H[b] Total feldspar as sampled	18				15			1			13			

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	28			29	30			31		
Type of deposit	Outwash			Dune	Outwash			Outwash		
Calcareous	Yes			No	Yes			Yes		
% retained on 8-mesh	None			None	30			26		
Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)										
Mesh / Condition:[b]	A Natural	B Acid treated	C % Acid soluble	A Natural	A Natural	B Acid treated	C % Acid soluble	A Natural	B Acid treated	C % Acid soluble
10				Tr.	27.4	22.4	47	3.7	2.1	51
14	Tr.	Tr.		0.1	21.2	18.7	43	4.9	3.5	41
20	0.1	0.1		0.5	15.3	16.1	32	7.5	6.0	33
28	0.9	0.8	33	2.2	18.1	22.7	18	16.4	16.4	17
35	6.1	5.5	31	8.0	9.4	12.1	17	22.8	24.2	12
48	25.1	25.1	24	24.6	2.8	3.5	18	23.8	27.3	5
65	29.4	32.4	16	23.9	0.6	0.7	25	9.1	10.5	4
100	23.2	28.3	7	24.0	0.4	0.5	13	7.1	8.2	4
150	4.1	4.7	13	6.9	0.3	0.4		0.9	0.9	11
200	1.5	1.6	20	3.5	0.2	0.5		0.2	0.3	
270	0.4	0.3		0.5	0.2	0.2		0.1	0.1	
—270	9.3	0.8		5.5	3.8	1.8		3.5	0.3	
Total	100.1	99.6	16	99.7	99.7	99.6	31	100.0	99.8	14

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated		E Acid Tr. (est.)	F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated			E Acid treated (est.)	F Natural (est.)	D Acid treated		E Acid treated (est.)	F Natural (est.)
Mesh:	48	100	—8+270	—8+270	48	100	—8+270	20	35	100	—8+270	—8+270	28	48	—8+270	—8+270
Quartz	70	83	76	63	82	79	79	45	82	82	45	32	67	75	69	59
Potash feldspar	8	7	8	7	4	11	8	3	5	7	3	2	5	5	5	4
Soda-lime feldspar	6	7	7	6	7	7	8	15	7	10	12	8	12	12	12	10
Shale, etc.	13	3	8	7	6	2	3	15	3	+	13	9	7	6	7	6
Chert	3	0	1	1	1	+	1	16	2	0	15	10	6	1	4	4
Heavy minerals	0	0	+	+	0	1	1	0	0	1	+	+	0	0	+	+
Others	0	0	+	16	+	+	+	6	1	+	12	39	3	1	3	17
Condition G[b]																
Total feldspar																
Acid treated	14	14	15		11	18		18	12	17	15		17	17	17	
Natural	11	13		13			16	13	10	15		10	15	16		14
Condition H[b]																
Total feldspar as sampled	12				15			7					10			

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	32	33	34
Type of deposit	Outwash	Dune	Outwash
Calcareous	Yes	No	Yes
% retained on 8-mesh	None	None	16

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	32 A Natural	32 B Acid treated	32 C % Acid soluble	33 A Natural	34 A Natural	34 B Acid treated	34 C % Acid soluble
10	Tr.	Tr.		0.2	9.5	6.3	48
14	Tr.	Tr.		1.0	10.3	7.6	42
20	Tr.	Tr.		2.0	8.3	6.5	26
28	0.2	0.1	33	6.3	8.8	8.9	20
35	0.5	0.4	30	26.2	10.4	11.3	13
48	1.8	1.8	20	41.2	28.2	31.6	11
65	5.9	6.8	12	12.0	16.4	19.8	4
100	25.1	28.6	12	5.7	5.4	6.1	10
150	23.8	27.1	13	1.9	0.5	0.6	0
200	26.7	28.0	19	1.1	0.3	0.3	
270	6.5	5.5	35	0.2	0.1	0.1	
—270	9.3	1.2		3.1	1.7	0.6	
Total	99.8	99.5	15	100.9	99.9	99.7	20

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	32 D Acid treated		32 E Acid treated (est.)	32 F Natural (est.)	33 D Acid treated				33 F Natural (est.)	34 D Acid treated		34 E Acid treated (est.)	34 F Natural (est.)
Mesh:	100	200	—8+270	—8+270	28	35	48	100	—8+270	48	65	—8+270	—8+270
Quartz	74	74	75	64	64	78	77	68	75	78	79	68	55
Potash feldspar	10	10	10	8	6	5	7	11	7	5	7	6	5
Soda-lime feldspar	9	11	10	8	13	8	9	13	10	7	8	9	7
Shale, etc.	5	2	3	3	7	6	5	+	5	7	5	8	6
Chert	1	0	+	+	4	2	1	0	1	2	+	5	4
Heavy minerals	+	2	1	1	0	0	0	8	1	0	+	+	+
Others	1	1	1	16	6	1	1	+	1	1	1	4	23
Condition G[b] Total feldspar													
Acid treated	19	21	20		19	13	16	24		12	15	15	
Natural	17	17		16					17	10	14		12
Condition H[b] Total feldspar as sampled	15				16					10			

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	35	36	37	38
Type of deposit	Outwash	Dune	Dune	Dune
Calcareous	Yes	No	No	Yes
% retained on 8-mesh	None	None	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	35 A Natural	35 B Acid Treated	35 C % Acid Soluble	36 A Natural	37 A Natural	38 A Natural	38 B Acid Treated	38 C % Acid Soluble
10	0.1	Tr.		Tr.				
14	0.1	0.1		0.1	Tr.	0.1	0.1	
20	0.3	0.3	17	0.1	0.1	0.2	0.2	
28	1.4	1.3	18	1.0	0.6	1.1	0.9	27
35	3.6	3.3	18	4.1	2.9	5.6	5.8	7
48	18.9	18.1	13	17.6	18.9	31.1	31.7	8
65	46.7	47.0	7	33.4	24.4	34.5	35.3	8
100	25.6	27.1	4	30.6	31.2	20.8	20.4	12
150	2.0	1.8	17	5.0	12.0	4.0	3.6	20
200	0.7	0.6	29	2.2	5.7	1.8	1.4	28
270	0.1	0.1		0.5	0.6	0.2	0.1	
—270	1.3	0.2		5.2	3.8	0.8	0.2	
Total	99.8	99.9	9	99.8	100.2	100.2	99.7	9

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	35 D Acid treated		35 E Acid treated (est.)	35 F Natural (est.)	36 D Acid treated			36 F Natural (est.)	37 D Acid treated				37 F Natural (est.)	38 D Acid treated			38 E Acid Tr. (est.)	38 F Natural (est.)
Mesh:	48	100	—8+270	—8+270	48	65	100	—8+270	48	65	100	150	—8+270	48	65	100	—8+270	—8+270
Quartz	79	77	79	72	84	81	77	79	82	79	77	69	77	80	78	74	76	69
Potash feldspar	4	11	8	7	7	9	11	9	7	8	9	14	9	6	8	8	8	7
Soda-lime feldspar	9	8	8	7	5	5	10	7	7	9	11	12	10	9	8	11	10	9
Shale, etc.	5	2	3	3	3	2	0	2	3	2	2	+	2	4	4	3	4	4
Chert	2	+	1	1	+	1	0	+	+	+	0	0	+	+	+	+	+	+
Heavy minerals	0	1	+	+	0	1	2	2	0	+	1	3	1	0	+	3	1	1
Others	1	1	1	10	1	1	+	1	1	2	+	2	1	1	2	1	1	10
Condition G[b] Total feldspar																		
Acid treated	13	19	16		12	14	21		14	17	20	26		15	16	19	18	
Natural	11	18		14				16					19	14	15	17		16
Condition H[b] Total feldspar as sampled	14				15				18					16				

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

Table 2.—Sieve and Mineral Analyses—Continued

Sample No.[a]	39	40	41	42
Type of deposit	Dune	Dune	Dune	Dune
Calcareous	No	No	No	No
% retained on 8-mesh	None	None	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Condition:[b] / Mesh	A Natural	A Natural	A Natural	A Natural
10		Tr.		
14	Tr.	0.2		
20	0.1	0.4		
28	0.9	2.9	0.1	Tr.
35	9.0	13.8	0.1	Tr.
48	41.6	40.0	1.8	3.5
65	30.8	24.4	13.1	19.3
100	10.6	12.0	53.2	47.1
150	1.4	2.2	18.6	10.6
200	0.9	1.0	8.4	10.0
270	0.2	0.2	0.9	1.0
—270	4.2	2.7	3.5	8.4
Total	99.7	99.8	99.7	99.9

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated				F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated				F Natural (est.)
Mesh:	35	48	65	100	—8+270	48	100	—8+270	65	100	150	—8+270	65	100	150	200	—8+270
Quartz	78	81	78	74	78	80	77	78	81	73	73	73	79	74	66	56	72
Potash feldspar	5	6	8	11	7	6	10	7	8	11	9	10	8	9	13	9	9
Soda-lime feldspar	7	7	9	12	9	9	9	9	9	13	16	14	8	11	16	16	12
Shale, etc.	7	4	4	1	4	4	2	4	1	1	+	1	4	2	+	0	2
Chert	2	1	+	0	1	1	0	1	+	0	0	+	+	+	0	0	+
Heavy minerals	0	0	+	2	+	0	2	+	+	1	1	1	+	3	4	16	4
Others	1	1	1	+	1	+	+	1	1	1	1	1	1	1	1	3	1
Condition G[b] Total feldspar																	
Acid treated	12	13	17	23		15	19		17	24	25		16	20	29	25	
Natural					16			16				24					21
Condition H[b] Total feldspar as sampled	15					16			23				19				

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	43	44	45	46	47
Type of deposit	Dune	Dune	Dune	Dune	Dune
Calcareous	No	No	No	No	No
% retained on 8-mesh	None	None	None	None	None
Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)					
Condition:[b]	A Natural	A Natural	A Natural	A Natural	A Natural
Mesh					
10			Tr.		
14	Tr.		Tr.		Tr.
20	Tr.	Tr.	0.2	Tr.	0.1
28	0.1	0.8	3.0	0.3	0.6
35	0.3	4.2	13.4	2.6	5.7
48	4.6	20.3	39.0	20.9	28.2
65	21.0	32.4	29.6	36.0	34.6
100	52.8	34.2	12.8	31.5	26.0
150	14.0	2.6	1.0	4.8	3.1
200	4.8	0.8	0.3	1.3	0.7
270	0.4	Tr.	0.1	0.1	Tr.
—270	2.4	4.5	0.7	2.1	0.9
Total	100.4	99.8	100.1	99.6	99.9

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated			F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated		F Natural (est.)
Mesh:	65	100	150	—8+270	48	65	100	—8+270	48	100	—8+270	48	65	100	—8+270	48	100	—8+270
Quartz	82	82	72	80	76	79	75	76	81	78	79	85	82	78	81	82	80	80
Potash feldspar	9	9	13	10	8	8	10	9	6	9	7	5	8	11	9	5	8	7
Soda-lime feldspar	5	6	9	6	8	7	11	9	6	8	7	6	6	7	6	8	8	8
Shale, etc.	2	1	+	1	6	4	2	4	5	3	5	3	3	1	2	4	1	3
Chert	1	+	0	+	2	1	+	1	1	+	1	+	+	0	+	+	+	+
Heavy minerals	+	+	5	1	0	+	1	+	0	1	+	0	+	2	1	0	2	1
Others	1	2	1	2	+	1	1	1	1	1	1	1	1	1	1	1	1	1
Condition G[b]																		
Total feldspar:																		
Acid treated	14	15	22		16	15	21		12	17		11	14	18		13	16	
Natural				16				18			14				15			15
Condition H[b]																		
Total feldspar as sampled	16				17				14			15				15		

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

Table 2.—Sieve and Mineral Analyses—Continued

Sample No.[a]	48	49	50
Type of deposit	Dune	Outwash	Outwash
Calcareous	No	Yes	Yes
% retained on 8-mesh	None	8	42

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	48: A Natural	49: A Natural	49: B Acid treated	49: C % Acid soluble	50: A Natural	50: B Acid treated	50: C % Acid soluble
10		3.4	2.4	41	8.3	7.2	30
14	0.1	3.0	2.5	32	8.6	7.5	30
20	0.5	3.4	3.2	24	8.7	8.2	24
28	2.4	9.2	9.2	18	15.1	15.9	16
35	12.0	18.4	19.0	15	21.2	22.2	16
48	35.8	35.2	36.7	14	24.0	24.9	17
65	29.0	18.7	20.2	11	8.8	9.2	16
100	17.6	6.3	5.7	25	3.9	3.6	28
150	2.1	0.6	0.4	50	0.5	0.4	40
200	0.5	0.3	0.1		0.2	0.2	
270	Tr.	0.1	0.1		0.1	0.1	
—270	0.8	1.3	0.2		0.6	0.4	
Total	100.8	99.9	99.7	17	100.0	99.8	19

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	48: D Acid treated				48: F Natural (est.)	49: D Acid treated		49: E Acid treated (est.)	49: F Natural (est.)	50: D Acid treated		50: E Acid treated (est.)	50: F Natural (est.)
Mesh:	35	48	65	100	—8+270	28	48	—8+270	—8+270	28	48	—8+270	—8+270
Quartz	90	91	90	91	90	65	83	77	63	59	81	67	54
Potash feldspar	3	3	4	4	4	4	7	7	6	4	4	4	3
Soda-lime feldspar	3	3	4	4	4	9	6	8	7	12	8	11	9
Shale, etc.	1	1	1	+	1	7	1	2	2	7	4	5	4
Chert	2	+	+	+	+	13	2	5	4	17	2	11	9
Heavy minerals	0	0	0	1	+	0	+	+	+	0	+	+	+
Others	1	2	1	+	1	2	1	1	18	1	1	2	21
Condition G[b]													
Total feldspar													
Acid treated	6	6	8	8		13	13	15		16	12	15	
Natural					8	11	11		13	14	10		12
Condition H[b]													
Total feldspar as sampled	8					12				7			

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	51			52	53	54
Type of deposit	Outwash			Dune	Dune	Dune
Calcareous	Yes			No	No	No
% retained on 8-mesh	1			None	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	A Natural	B Acid treated	C % Acid soluble	A Natural	A Natural	A Natural
10	0.4	0.2	57			
14	0.4	0.3	37	Tr.		
20	0.7	0.6	36	0.1	0.1	0.1
28	2.5	2.4	30	0.4	0.4	0.4
35	10.9	11.1	20	2.5	5.8	3.3
48	32.1	32.8	19	11.6	27.8	16.8
65	25.1	27.0	14	26.2	32.9	29.4
100	18.7	19.5	17	43.2	27.8	38.4
150	4.7	3.9	33	9.0	3.8	7.6
200	2.5	1.5	51	3.6	0.7	2.4
270	0.5	0.3	60	0.4	0.1	0.2
—270	1.4	0.4		2.4	0.6	1.4
Total	99.9	100.0	19	99.4	100.0	100.0

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated		E Acid treated (est.)	F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated		F Natural (est.)
Mesh:	48	100	—8+270	—8+270	48	100	200	—8+270	48	65	100	—8+270	65	100	—8+270
Quartz	86	81	82	66	86	91	71	87	86	87	85	85	90	92	88
Potash feldspar	4	8	6	5	5	6	10	6	4	5	6	5	5	4	5
Soda-lime feldspar	5	8	6	5	5	3	12	5	5	4	6	5	4	3	4
Shale, etc.	3	1	3	2	2	+	0	1	2	2	1	2	1	1	1
Chert	+	1	1	1	2	+	0	1	2	1	+	1	+	0	1
Heavy minerals	1	1	1	1	0	+	4	+	0	0	1	1	+	+	1
Others	1	+	1	20	+	+	3	+	1	1	1	1	+	+	+
Condition G[b]															
Total feldspar															
Acid treated	9	16	12		10	9	22		9	9	12		9	7	
Natural	7	13		10				11				10			9
Condition H[b]															
Total feldspar															
as sampled	10				11				10				9		

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	55	56			57
Type of deposit	Dune	Dune			Dune
Calcareous	No	Yes			No
% retained on 8-mesh	None	None			None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Condition:[b] / Mesh	A Natural	A Natural	B Acid treated	C % Acid soluble	A Natural
10	Tr.				Tr.
14	0.7	0.1	0.1		0.3
20	2.0	0.3	0.3		0.6
28	6.0	2.2	2.4	0	2.2
35	13.6	10.8	11.2	3	10.7
48	30.4	31.4	32.4	5	29.3
65	27.0	25.3	25.6	7	23.8
100	14.5	20.6	20.6	8	19.3
150	1.7	5.0	4.8	12	5.2
200	0.4	2.7	2.2	26	4.3
270	0.2	0.4	0.3		1.2
—270	3.0	0.8	0.1		2.6
Total	99.5	99.6	100.0	7	99.5

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated			F Natural (est.)	D Acid treated					E Acid treated (est.)	F Natural (est.)	D Acid treated					F Natural (est.)
Mesh:	28	48	100	—8+270	28	48	65	100	200	—8+270	—8+270	28	48	65	150	200	—8+270
Quartz	64	85	92	83	70	83	85	80	63	81	75	61	84	85	73	68	79
Potash feldspar	5	6	4	5	2	4	6	7	12	6	5	3	5	5	10	9	6
Soda-lime feldspar	10	6	3	6	8	7	5	10	19	8	8	13	7	8	12	14	9
Shale, etc.	3	2	+	2	3	3	2	1	+	2	2	5	3	1	+	0	2
Chert	14	1	0	3	15	2	1	+	+	2	2	14	1	+	+	0	2
Heavy minerals	0	0	+	+	0	0	+	1	4	+	+	0	0	+	5	8	1
Others	4	+	1	1	2	1	1	1	2	1	8	4	+	1	+	1	1
Condition G[b]																	
Total feldspar:																	
Acid treated	15	12	7		10	11	11	17	31	14		16	12	13	22	23	
Natural				11		10	10	16	23		13						15
Condition H[b]																	
Total feldspar as sampled	11				13							15					

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	58			59	60	61
Type of deposit	Dune			Dune	Dune	Dune
Calcareous	Yes			No	No	No
% retained on 8-mesh	None			None	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	A Natural	B Acid treated	C % Acid soluble	A Natural	A Natural	A Natural
10						
14	Tr.			Tr.		
20	0.1	0.1		Tr.		Tr.
28	0.4	0.4		0.1		0.2
35	4.4	4.8	5	0.7	1.6	0.6
48	30.0	31.5	7	12.0	11.2	6.7
65	32.8	33.8	8	27.8	13.6	21.7
100	21.2	21.2	11	35.2	22.8	45.4
150	5.0	4.3	24	10.8	18.8	12.6
200	3.6	2.7	33	7.8	15.6	8.6
270	1.0	0.5	60	1.4	4.0	1.9
—270	1.4	0.1		3.3	12.2	2.2
Total	99.9	99.4	10	99.1	99.8	99.9

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated		E Acid treated (est.)	F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated			F Natural (est.)
Mesh:	65	100	—8+270	—8+270	65	100	—8+270	48	65	100	—8+270	65	100	150	—8+270
Quartz	84	77	80	72	80	76	76	83	78	79	76	74	80	66	73
Potash feldspar	7	9	8	7	8	11	10	8	8	7	8	8	8	11	9
Soda-lime feldspar	6	10	8	7	8	10	10	5	10	12	12	16	11	18	15
Shale, etc.	2	2	2	2	3	+	1	2	+	0	+	1	+	+	+
Chert	+	0	1	1	+	+	+	+	0	0	+	+	0	0	+
Heavy minerals	+	1	+	+	+	1	2	+	2	1	3	+	1	4	2
Others	1	1	1	11	1	2	1	2	2	1	1	1	+	1	1
Condition G[b]															
Total feldspar															
Acid treated	13	19	16		16	21		13	18	19		24	19	29	
Natural	12	17		14			20				20				24
Condition H[b]															
Total feldspar															
as sampled	14				19			18				23			

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	62	63	64	65
Type of deposit	Outwash	Outwash	Dune	Outwash
Calcareous	Yes	Yes	No	No
% retained on 8-mesh	26	None	None	7

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Sample No.	62			63			64	65
Condition:[b] / Mesh	A Natural	B Acid treated	C % Acid soluble	A Natural	B Acid treated	C % Acid soluble	A Natural	A Natural
10	4.9	3.9	32					2.8
14	4.9	4.2	26				Tr.	4.4
20	5.8	5.7	17				Tr.	7.9
28	14.7	15.8	9	0.2	0.4		0.1	21.7
35	24.7	26.2	10	1.2	2.0	8	0.8	27.4
48	24.5	26.1	10	5.4	9.3	4	20.8	24.4
65	9.3	9.9	9	10.5	17.8	5	44.0	7.2
100	5.2	5.3	13	19.4	32.8	5	27.0	2.6
150	1.5	1.4	21	8.8	14.6	7	2.6	0.2
200	1.0	0.8	30	10.2	15.6	14	0.8	0.1
270	0.3	0.2		5.4	6.8	30	0.1	0.1
—270	3.0	0.2		39.0	1.6		4.5	1.4
Total	99.8	99.7	12	100.1	100.9	8	100.7	100.2

Mineral Analyses (Per Cent by Number of Grains)

Sample No.	62				63				64			65		
Condition:[b]	D Acid treated		E Acid treated (est.)	F Natural (est.)	D Acid treated		E Acid treated (est.)	F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated		F Natural (est.)
Mesh:	28	48	—8+270	—8+270	100	150	—8+270	—8+270	48	100	—8+270	28	48	—8+270
Quartz	61	81	70	62	73	72	72	66	73	71	73	66	75	70
Potash feldspar	2	5	4	3	11	9	10	9	8	7	7	4	5	5
Soda-lime feldspar	14	9	11	10	12	14	13	12	11	17	14	18	13	16
Shale, etc.	4	4	4	3	2	2	2	2	5	3	4	6	5	5
Chert	18	1	9	8	0	0	+	+	1	+	+	3	+	1
Heavy minerals	0	0	+	+	1	3	2	2	0	1	1	0	+	+
Others	1	+	2	14	1	+	1	9	2	1	1	3	2	3
Condition G[b] Total feldspar														
Acid treated	16	14	15		23	23	23		19	24		22	18	
Natural	15	13		13	22	21		21			21			21
Condition H[b] Total feldspar as sampled	9				13				20			19		

Table 2.—Sieve and Mineral Analyses—Continued

Sample No.[a]	66	67	68	69
Type of deposit	Dune	Dune	Dune	Outwash
Calcareous	No	No	No	No
% retained on 8-mesh	Trace	None	None	49

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Condition:[b] / Mesh	A Natural	A Natural	A Natural	A Natural
10	Tr.	Tr.		17.2
14	0.1	0.1	Tr.	13.0
20	0.2	0.1	0.1	9.7
28	0.4	0.9	1.4	10.9
35	3.1	6.5	13.0	12.8
48	41.0	37.8	47.2	17.6
65	42.0	35.3	26.4	11.6
100	10.8	16.1	9.6	5.2
150	0.6	2.0	1.4	0.7
200	0.2	0.6	0.6	0.2
270	0.1	0.1	0.2	0.1
—270	1.6	0.7	0.9	0.7
Total	100.1	100.2	100.8	99.7

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated		F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated					F Natural (est.)
Mesh:	48	65	—8+270	48	65	100	—8+270	48	65	—8+270	10	14	28	48	100	—8+270
Quartz	73	75	73	75	73	70	73	75	79	76	25	32	63	74	73	56
Potash feldspar	6	7	7	9	9	6	8	8	7	8	5	8	5	6	8	6
Soda-lime feldspar	14	13	13	11	15	20	14	11	10	11	18	18	17	14	13	16
Shale, etc.	5	3	4	2	2	+	2	5	3	4	6	2	3	2	+	3
Chert	1	+	1	1	+	0	1	+	+	+	1	1	1	+	+	+
Heavy minerals	0	1	1	0	+	2	+	0	+	+	0	0	0	+	3	+
Others	1	1	1	2	1	2	2	1	1	1	45	39	11	4	3	19
Condition G[b]																
Total feldspar																
Acid treated	20	20		20	24	26		19	17		23	26	22	20	21	
Natural			20				22			19						22
Condition H[b]																
Total feldspar																
as sampled	20			22				19			11					

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	70	71	72	73	74
Type of deposit	Dune	Outwash	Dune	Dune	Outwash
Calcareous	No	No	No	No	No
% retained on 8-mesh	None	1	None	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	A Natural	A Natural	A Natural	A Natural	A Natural
10	Tr.	0.6			
14	0.2	1.2			
20	0.8	1.2		Tr.	Tr.
28	3.5	3.4	0.2	0.2	1.2
35	13.2	8.0	2.4	1.0	16.4
48	39.0	32.4	35.8	13.4	51.6
65	23.0	36.2	42.2	34.6	24.4
100	13.9	14.6	16.0	42.6	5.6
150	2.7	1.4	1.2	5.4	0.2
200	1.4	0.4	0.6	1.6	Tr.
270	0.3	Tr.	0.2	0.2	Tr.
—270	1.4	0.8	1.8	1.2	0.2
Total	99.4	100.2	100.4	100.2	99.6

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated		F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated		F Natural	D Acid treated		F Natural (est.)	
Mesh:	48	100	—8+270	48	65	100	—8+270	48	65	—8+270	65	100	—8+270	35	48	65	—8+270
Quartz	77	78	76	71	76	70	72	74	71	72	77	75	75	67	76	74	74
Potash feldspar	7	7	7	7	8	9	8	9	8	8	9	10	9	11	8	7	8
Soda-lime feldspar	10	10	10	16	13	17	15	13	16	15	9	10	10	14	13	16	14
Shale, etc.	5	3	5	3	1	+	2	3	3	3	4	2	3	4	2	1	2
Chert	+	0	+	+	0	+	+	+	+	+	+	+	+	1	+	0	+
Heavy minerals	0	2	1	+	+	2	+	0	+	+	0	1	1	0	0	1	+
Others	1	+	1	3	2	2	3	1	2	2	1	2	2	3	1	1	2
Condition G[b] Total feldspar: Acid treated	17	17		23	21	26		22	24		18	20		25	21	23	
Natural			17				23			23			19				22
Condition H[b] Total feldspar as sampled	17			23				23			19			22			

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	75	76	77	78
Type of deposit	Dune	Dune	Outwash	Outwash
Calcareous	No	No	No	No
% retained on 8-mesh	None	None	None	6

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Condition:[b] / Mesh	A Natural	A Natural	A Natural	A Natural
10	Tr.		Tr.	4.8
14	0.1	Tr.	0.1	8.3
20	0.4	Tr.	0.1	11.3
28	2.7	0.2	0.8	19.1
35	11.4	1.8	4.4	18.8
48	39.4	26.2	25.5	17.8
65	20.0	42.0	38.6	7.7
100	19.4	24.6	22.3	3.4
150	4.3	3.2	3.1	0.7
200	1.3	1.2	1.2	0.5
270	0.2	0.2	0.3	0.2
−270	1.6	1.4	3.4	7.4
Total	100.8	100.8	99.8	100.0

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated		F Natural (est.)	D Acid treated			F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated			F Natural (est.)
Mesh:	48	100	−8+270	48	65	100	−8+270	48	100	−8+270	14	28	48	−8+270
Quartz	76	75	75	71	72	72	71	93	87	90	16	52	78	56
Potash feldspar	4	9	6	8	9	7	8	2	4	3	3	6	6	6
Soda-lime feldspar	13	11	12	13	13	16	14	3	6	5	6	10	8	8
Shale, etc.	6	3	5	6	3	2	4	1	+	+	26	14	5	12
Chert	+	+	+	1	+	+	+	+	+	+	34	16	2	14
Heavy minerals	0	1	1	0	1	1	1	0	0	+	0	0	+	+
Others	1	1	1	1	2	2	2	1	3	2	15	2	1	4
Condition G[b] Total feldspar Acid treated	17	20		21	22	23		5	10		9	16	14	
Natural			18				22			8				14
Condition H[b] Total feldspar as sampled	18			22				8			12			

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	79	80	81
Type of deposit	Dune	River	River
Calcareous	No	Yes	Yes
% retained on 8-mesh	None	1	6

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	79: A Natural	80: A Natural	80: B Acid treated	80: C % Acid soluble	81: A Natural	81: B Acid treated	81: C % Acid soluble
10		0.5	0.3	33	3.2	2.3	34
14		1.1	1.0	18	4.3	3.5	28
20		3.3	3.3	6	4.9	4.2	25
28	0.1	12.2	12.4	4	13.0	12.4	17
35	1.7	28.3	28.5	5	27.8	28.2	11
48	12.8	35.7	36.1	4	30.1	32.0	6
65	29.3	12.4	12.6	4	10.9	12.0	3
100	39.9	5.2	5.1	7	3.9	4.2	5
150	10.4	0.6	0.5	9	0.3	0.3	
200	3.5	0.2	0.2		0.1	0.1	
270	0.3	0.1	0.1		Tr.	0.1	
—270	1.6	0.4	0.1		1.7	0.5	
Total	99.6	100.0	100.2	5	100.2	99.8	12

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	79: D Acid treated		79: F Natural (est.)	80: D Acid treated		80: E Acid treated (est.)	80: F Natural (est.)	81: D Acid treated		81: E Acid treated (est.)	81: F Natural (est.)
Mesh:	65	100	—8+270	35	48	—8+270	—8+270	35	48	—8+270	—8+270
Quartz	66	64	64	82	87	84	80	76	81	75	66
Potash feldspar	12	16	14	6	5	6	5	4	5	5	4
Soda-lime feldspar	16	13	15	4	4	4	4	6	7	7	6
Shale, etc.	3	2	2	3	1	2	2	6	2	5	4
Chert	+	0	+	1	+	1	1	6	5	6	6
Heavy minerals	0	3	2	+	+	+	+	1	+	1	1
Others	3	2	3	4	3	3	8	1	+	1	13
Condition G[b]											
Total feldspar											
Acid treated	28	29		10	9	10		10	12	12	
Natural			29	9	9		9	9	11		10
Condition H[b]											
Total feldspar as sampled	29			9				9			

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	82	83	84
Type of deposit	River	River	River
Calcareous	Yes	Yes	Yes
% retained on 8-mesh	29	4	10

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	82 A Natural	82 B Acid treated	82 C % Acid soluble	83 A Natural	83 B Acid treated	83 C % Acid soluble	84 A Natural	84 B Acid treated	84 C % Acid soluble
10	3.6	2.9	31	4.2	4.0	6	2.1	2.1	5
14	5.2	4.1	33	8.8	8.6	5	2.0	2.1	+2
20	6.1	5.3	24	13.8	13.4	5	7.7	8.1	1
28	10.7	10.7	15	23.5	23.6	2	35.1	35.6	2
35	16.8	18.4	7	25.3	25.5	2	36.7	36.7	3
48	28.6	31.5	6	19.9	20.4	0	13.3	13.4	2
65	15.4	17.6	3	3.7	3.8	+3	1.4	1.4	4
100	6.8	7.3	7	0.5	0.5	0	0.5	0.4	11
150	1.1	1.2	9	0.1	0.1		0.1	0.1	
200	0.5	0.5	11	Tr.	0.1		0.1	0.1	
270	0.1	0.1		Tr.	Tr.		0.1	0.1	
—270	4.8	0.2		0.3	0.1		1.1	0.1	
Total	99.7	99.8	10	100.1	100.1	2	100.2	100.2	2

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	82 D Acid treated			82 E Acid treated (est.)	82 F Natural (est.)	83 D Acid treated				83 E Acid treated (est.)	83 F Natural (est.)	84 D Acid treated			84 E Acid treated (est.)	84 F Natural (est.)
Mesh:	35	48	65	—8+270	—8+270	14	20	35	48	—8+270	—8+270	28	35	48	—8+270	—8+270
Quartz	80	80	81	77	69	48	60	80	82	71	69	57	62	70	58	57
Potash feldspar	4	5	6	5	4	11	7	7	6	7	7	10	11	10	11	10
Soda-lime feldspar	8	9	8	9	8	19	22	9	8	14	14	15	14	13	14	14
Shale, etc.	4	3	2	4	4	2	6	2	2	3	3	10	8	3	9	9
Chert	3	2	1	3	3	3	3	1	1	2	2	3	2	1	3	3
Heavy minerals	+	0	+	+	+	0	0	0	+	+	+	+	1	1	1	1
Others	1	1	2	2	12	17	2	1	1	3	5	5	2	2	4	6
Condition G[b] Total feldspar																
Acid treated	12	14	14	14		30	29	16	14	21		25	25	23	25	
Natural	11	13	14		12	28	28	16	14		21	24	24	23		24
Condition H[b] Total feldspar as sampled	8					20						21				

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	85	86	87
Type of deposit	River	River	River
C lcareous	No	No	Yes
% retained on 8-mesh	1	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	85: A Natural	86: A Natural	87: A Natural	87: B Acid treated	87: C % Acid soluble
10	0.3		0.2	0.2	
14	1.1		0.4	0.4	
20	3.0	Tr.	0.6	0.5	9
28	7.3	Tr.	2.6	2.6	4
35	16.3	4.4	10.2	10.0	4
48	44.1	48.5	43.7	41.0	8
65	22.6	33.0	33.5	36.3	+6
100	4.5	12.0	8.3	8.8	+4
150	0.3	1.4	0.2	0.2	
200	0.1	0.3	0.1	0.1	
270	Tr.	Tr.	Tr.	Tr.	
—270	0.4	0.4	0.3	Tr.	
Total	100.0	100.0	100.1	100.1	2

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	85: D Acid treated			85: F Natural (est.)	86: D Acid treated			86: F Natural (est.)	87: D Acid treated				87: E Acid treated (est.)	87: F Natural (est.)
Mesh:	35	48	65	—8+270	48	65	100	—8+270	35	48	65	100	—8+270	—8+270
Quartz	71	77	79	75	82	78	80	81	75	80	75	75	77	75
Potash feldspar	8	8	6	8	5	5	5	5	8	6	6	7	6	6
Soda-lime feldspar	12	11	11	11	10	13	12	11	13	10	15	14	13	13
Shale, etc.	3	1	2	2	1	1	+	1	2	1	1	1	1	1
Chert	2	1	+	1	0	1	+	+	+	+	+	0	+	+
Heavy minerals	0	+	+	+	+	+	1	+	+	+	1	2	1	1
Others	4	2	2	3	2	2	2	2	2	3	2	1	2	4
Condition G[b]														
Total feldspar:														
Acid treated	20	19	17		15	18	17		21	16	21	21	19	
Natural				19				16	20	15	21	21		19
Condition H[b] Total feldspar as sampled	19				16				19					

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	88	89	90
Type of deposit	River	River	River
Calcareous	Yes	Yes	Yes
% retained on 8-mesh	None	7	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Condition:[b] Mesh	88 A Natural	88 C % Acid soluble	89 A Natural	89 B Acid treated	89 C % Acid soluble	90 A Natural	90 B Acid treated	90 C % Acid soluble
10			3.0	2.8	7			
14			4.0	4.0	3			
20	Tr.		6.8	6.7	3	Tr.	Tr.	
28	3.0		18.3	18.1	2	0.1	0.1	
35	15.6		25.9	26.0	1	0.1	0.1	
48	40.2		29.0	29.0	2	1.4	1.2	14
65	30.0		10.0	10.4	+2	30.4	26.6	15
100	11.2		2.7	2.8	+4	51.0	55.1	+4
150	0.4		0.3	0.3		11.6	12.4	+3
200	Tr.		0.1	0.1		4.3	4.2	7
270	Tr.		Tr.	Tr.		0.4	0.4	
—270	0.4		0.1	Tr.		0.8	Tr.	
Total	100.8	2	100.2	100.2	1	100.1	100.1	3

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	88 D Acid treated		88 F Natural (est.)	89 D Acid treated			89 E Acid treated (est.)	89 F Natural (est.)	90 D Acid treated			90 E Acid treated (est.)	90 F Natural (est.)
Mesh:	48	65	—8+270	28	35	48	—8+270	—8+270	65	100	150	—8+270	—8+270
Quartz	70	71	67	67	72	76	71	72	60	57	60	58	55
Potash feldspar	8	7	8	10	9	8	9	9	12	11	9	11	11
Soda-lime feldspar	14	16	15	13	14	13	14	14	21	24	25	23	23
Shale, etc.	3	3	3	1	1	1	1	1	3	3	1	3	3
Chert	2	1	2	2	1	+	1	1	1	+	0	+	+
Heavy minerals	1	1	1	0	0	0	+	+	1	1	3	2	2
Others	2	1	4	7	3	2	4	5	2	4	2	3	6
Condition G[b] Total feldspar													
Acid treated	22	23		23	23	21	23		33	35	34		
Natural			23	23	23	21		23	28	35	34	34	34
Condition H[b] Total feldspar as sampled	23			21					34				

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	91	92
Type of deposit	River	River
Calcareous	Yes	Yes
% retained on 8-mesh	None	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	A Natural (91)	B Acid treated (91)	C % Acid soluble (91)	A Natural (92)	B Acid treated (92)	C % Acid soluble (92)
10	0.2	0.2		Tr.	Tr.	
14	0.2	0.2		Tr.	Tr.	
20	0.4	0.4		Tr.	Tr.	
28	0.9	0.9	0	Tr.	Tr.	
35	1.6	1.6	0	0.1	0.1	
48	5.1	5.3	2	0.1	0.1	
65	18.9	18.0	10	1.0	1.0	10
100	61.0	64.0	1	39.2	37.0	13
150	7.3	7.6	1	35.2	38.3	0
200	1.6	1.6	9	18.8	20.8	+12
270	0.4	0.4	12	2.6	2.4	15
—270	2.5	0.1		3.1	0.4	
Total	100.1	100.3	3	100.1	100.1	5

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated (91)				E Acid treated (est.) (91)	F Natural (est.) (91)	D Acid treated (92)			E Acid treated (est.) (92)	F Natural (est.) (92)
Mesh:	48	65	100	150	—8+270	—8+270	100	150	200	—8+270	—8+270
Quartz	64	49	55	54	54	52	56	55	60	55	52
Potash feldspar	16	13	10	9	11	11	11	9	8	10	9
Soda-lime feldspar	14	23	24	29	24	23	23	26	23	24	23
Shale, etc.	3	5	3	2	3	3	5	3	2	4	4
Chert	1	4	+	0	1	1	+	0	0	+	+
Heavy minerals	+	2	3	5	3	3	+	2	3	2	2
Others	2	4	5	1	4	7	5	5	4	5	10
Condition G[b]											
Total feldspar											
Acid treated	30	36	34	38	35		34	35	31	34	
Natural	29	32	34	38		34	30	35	31		32
Condition H[b]											
Total feldspar as sampled	33						31				

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	93	94
Type of deposit	River	River
Calcareous	Yes	Yes
% retained on 8-mesh	3	None

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	93 A Natural	93 B Acid treated	93 C % Acid soluble	94 A Natural	94 B Acid treated	94 C % Acid soluble
10	1.2	1.2	0			
14	2.8	2.7	4	Tr.	Tr.	
20	7.8	7.3	8	Tr.	Tr.	
28	23.0	22.6	3	0.1	0.1	
35	25.9	27.3	+4	0.8	0.7	7
48	29.5	29.1	3	24.7	22.4	11
65	8.4	8.2	4	61.2	63.0	+1
100	1.3	1.4	+7	11.9	13.2	+8
150	0.1	0.2		0.5	0.5	0
200	0.1	0.1		0.1	0.1	
270	Tr.	Tr.		0.1	Tr.	
—270	0.1	Tr.		0.6	Tr.	
Total	100.2	100.1	1	100.0	100.0	1

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	93 D Acid treated			93 E Acid treated (est.)	93 F Natural (est.)	94 D Acid treated			94 E Acid treated (est.)	94 F Natural (est.)
Mesh:	28	35	48	—8+270	—8+270	48	65	100	—8+270	—8+270
Quartz	66	72	67	67	66	64	67	56	65	64
Potash feldspar	11	12	13	12	12	13	10	10	11	11
Soda-lime feldspar	15	12	15	14	14	14	16	22	16	16
Shale, etc.	2	1	2	2	2	2	+	1	1	1
Chert	3	1	1	2	2	4	2	1	2	2
Heavy minerals	0	+	+	+	+	1	2	7	2	2
Others	3	2	2	3	4	2	3	3	3	4
Condition G[b] Total feldspar										
Acid treated	26	24	28	26		27	26	32	27	
Natural	25	24	27		26	24	26	32		27
Condition H[b] Total feldspar as sampled	25					27				

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	95	96
Type of deposit	River	River
Calcareous	Yes	Yes
% retained on 8-mesh	None	18

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	95 A Natural	95 B Acid treated	95 C % Acid soluble	96 A Natural	96 B Acid treated	96 C % Acid soluble
10				11.1	9.6	37
14	Tr.	Tr.		12.6	11.5	33
20	Tr.	Tr.		12.4	13.0	24
28	0.1	0.1		20.7	23.0	19
35	0.4	0.5		19.6	22.1	17
48	1.7	1.9	6	11.9	13.1	19
65	11.0	12.6	2	4.5	4.9	20
100	54.7	61.8	3	1.4	1.3	26
150	12.7	14.8	1	0.3	0.4	
200	6.4	6.9	8	0.4	0.4	
270	1.3	1.3	15	0.2	0.1	
—270	11.6	0.2		4.8	0.4	
Total	99.9	100.1	3	99.9	99.8	23

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	95 D Acid treated					95 E Acid treated (est.)	95 F Natural (est.)	96 D Acid treated			96 E Acid treated (est.)	96 F Natural (est.)
Mesh:	48	65	100	150	200	—8+270	—8+270	14	28	35	—8+270	—8+270
Quartz	61	57	66	58	53	62	60	24	51	67	49	38
Potash feldspar	13	12	7	12	8	9	8	4	4	5	5	4
Soda-lime feldspar	14	19	17	16	29	18	18	19	19	14	17	13
Shale, etc.	6	5	5	5	+	5	5	19	16	7	13	10
Chert	3	2	+	0	0	+	+	18	8	4	9	7
Heavy minerals	0	+	2	5	5	2	2	0	0	1	1	+
Others	3	5	3	4	5	4	7	16	2	2	6	28
Condition G[b] Total feldspar:												
Acid treated	27	31	24	28	37	27		23	23	19	22	
Natural	25	30	23	28	34		26	15	19	16		17
Condition H[b] Total feldspar as sampled	23							13				

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	97			98	99		
Type of deposit	River			River	River		
Calcareous	Yes			No	Yes		
% retained on 8-mesh	None			None	None		

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	A Natural	B Acid treated	C % Acid soluble	A Natural	A Natural	B Acid treated	C % Acid soluble
10	0.5	0.4	20	0.1			
14	1.3	1.0	24	0.3	Tr.	Tr.	
20	3.3	3.0	19	0.3	0.1	0.1	
28	10.4	10.3	10	0.4	0.4	0.3	
35	21.2	21.4	9	0.6	1.8	1.9	6
48	34.5	35.0	9	6.2	20.2	20.4	9
65	19.7	20.3	7	24.6	36.9	39.9	2
100	7.2	7.7	4	38.8	28.6	31.4	1
150	0.4	0.4		8.2	3.3	3.5	3
200	0.2	0.2		4.2	1.6	1.7	6
270	0.1	0.1		1.0	0.4	0.3	
—270	1.1	0.2		15.1	6.5	0.4	
Total	99.9	100.0	9	99.8	99.8	99.9	3

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated			E Acid treated (est.)	F Natural (est.)	D Acid treated		F Natural (est.)	D Acid treated		E Acid treated (est.)	F Natural (est.)
Mesh:	28	48	65	—8+270	—8+270	65	100	—8+270	65	100	—8+270	—8+270
Quartz	56	72	73	69	63	76	74	74	84	84	83	80
Potash feldspar	8	7	6	7	6	9	9	9	5	5	5	5
Soda-lime feldspar	14	12	14	14	13	10	10	10	7	6	7	7
Shale, etc.	6	5	3	3	3	3	3	3	3	1	3	3
Chert	11	2	+	2	2	1	1	1	+	0	+	+
Heavy minerals	0	+	2	2	2	1	2	2	+	2	1	1
Others	5	2	2	3	11	+	1	1	1	1	1	4
Condition G[b]												
Total feldspar												
Acid treated	22	19	20	21		19	19		12	11	12	
Natural	20	17	19		19			19	12	11		12
Condition H[b]												
Total feldspar as sampled	19					16			11			

[a] The locations of the samples are given in Table 1.
[b] The "condition" of the samples is described in detail at the beginning of this table.

TABLE 2.—SIEVE AND MINERAL ANALYSES—Continued

Sample No.[a]	100	101	102
Type of deposit	River	River	Till
Calcareous	Yes	Yes	Yes
% retained on 8-mesh	18	None	5

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	A Natural (100)	B Acid treated (100)	C % Acid soluble (100)	A Natural (101)	B Acid treated (101)	C % Acid soluble (101)	A Natural (102)	C % Acid soluble (102)
10	6.0	5.8	11				0.8	
14	6.1	5.6	16				1.4	
20	5.9	5.7	11	Tr.			1.3	
28	7.0	7.2	6	Tr.	Tr.		1.9	29
35	12.3	13.2	2	0.1	0.1		2.2	
48	24.0	25.9	1	3.4	3.5	3	3.8	21
65	11.2	12.0	2	26.5	23.6	17	3.5	
100	13.2	14.2	2	55.4	60.6	+2	5.7	18
150	5.9	6.3	3	9.4	10.1	0	3.2	
200	2.9	3.1	2	1.7	1.3	29	3.7	
270	0.5	0.4	11	0.2	0.2		3.0	
—270	5.1	0.3		3.3	0.3		69.4	
Total	100.1	99.7	3	100.0	99.7	4	99.9	

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated (100)			E Acid treated (est.) (100)	F Natural (est.) (100)	D Acid treated (101)		E Acid treated (est.) (101)	F Natural (est.) (101)	D Acid treated (102)			E Acid treated (est.) (102)
Mesh:	35	48	100	—8+270	—8+270	65	100	—8+270	—8+270	28	48	100	—8+270
Quartz	80	88	92	82	79	70	69	69	67	13	50	60	50
Potash feldspar	4	3	3	3	3	9	7	8	7	1	4	9	7
Soda-lime feldspar	5	5	3	5	5	12	17	16	15	5	6	9	8
Shale, etc.	3	2	+	3	3	4	2	2	2	76	38	20	31
Chert	7	1	0	4	4	1	0	+	+	2	1	+	1
Heavy minerals	+	+	1	1	1	+	2	2	2	0	+	+	1
Others	1	1	1	2	5	4	3	3	7	3	1	2	2
Condition G[b] Total feldspar													
Acid treated	9	8	6	8		21	24	24		6	10	18	15
Natural	9	8	6		8	17	24		22	4	8	15	

Condition H[b]	100	101	102
Total feldspar as sampled	6	21	

TABLE 2.—SIEVE AND MINERAL ANALYSES—Concluded

Sample No.[a]	103		104		105		106	
Type of deposit	Till		Till		Till		Till	
Calcareous	Yes		Yes		Yes		Yes	
% retained on 8-mesh	9		4		8		7	

Sieve Analyses of Material Finer Than 8-Mesh (Per Cent by Weight Retained) and Amount Acid Soluble (Per Cent by Weight)

Mesh / Condition:[b]	A Natural	C % Acid soluble	A Natural	C % Acid soluble	A Natural	C % Acid soluble	A Natural	C % Acid soluble
10	2.7		1.2		1.8		1.5	
14	3.1		1.9		2.2		2.0	
20	2.7		1.9		2.2		1.9	
28	3.4	50	3.4	20	3.2	31	2.7	38
35	4.4		4.9		4.4		3.5	
48	8.1	18	10.5	6	8.3	10	6.3	14
65	7.7		9.9		8.1		6.3	
100	10.9	15	11.4	7	10.3	11	8.6	13
150	5.4		5.6		4.8		4.4	
200	6.5		6.1		5.6		5.5	
270	3.3		2.4		2.5		2.5	
—270	41.5		40.7		46.2		51.8	
Total	99.7		99.9		99.6		100.0	

Mineral Analyses (Per Cent by Number of Grains)

Condition:[b]	D Acid treated			E Acid treated (est.)	D Acid treated			E Acid treated (est.)	D Acid treated			E Acid treated (est.)	D Acid treated			E Acid treated (est.)
Mesh:	28	48	100	—8+270	28	48	100	—8+270	28	48	100	—8+270	28	48	100	—8+270
Quartz	44	80	75	64	58	82	68	68	53	78	77	68	52	80	80	68
Potash feldspar	3	7	12	9	5	5	12	9	4	7	10	8	5	8	11	9
Soda-lime feldspar	14	5	8	9	13	7	12	11	8	7	8	9	10	6	5	6
Shale, etc.	21	4	3	8	11	5	6	6	23	4	2	7	20	3	1	7
Chert	14	2	0	6	11	1	0	4	9	2	1	4	9	1	0	4
Heavy minerals	0	0	1	1	0	0	+	+	0	0	1	1	0	+	2	3
Others	4	2	1	3	2	+	2	2	3	2	1	3	4	2	1	3
Condition G[b]																
Total feldspar																
Acid treated	17	12	20	18	18	12	24	20	12	14	18	17	15	14	16	15
Natural	9	10	17		15	11	22		8	13	16		9	12	14	
Condition H[b]																
Total feldspar as sampled																

a The locations of the samples are given in Table 1.
b The "condition" of the samples is described in detail at the beginning of this table.